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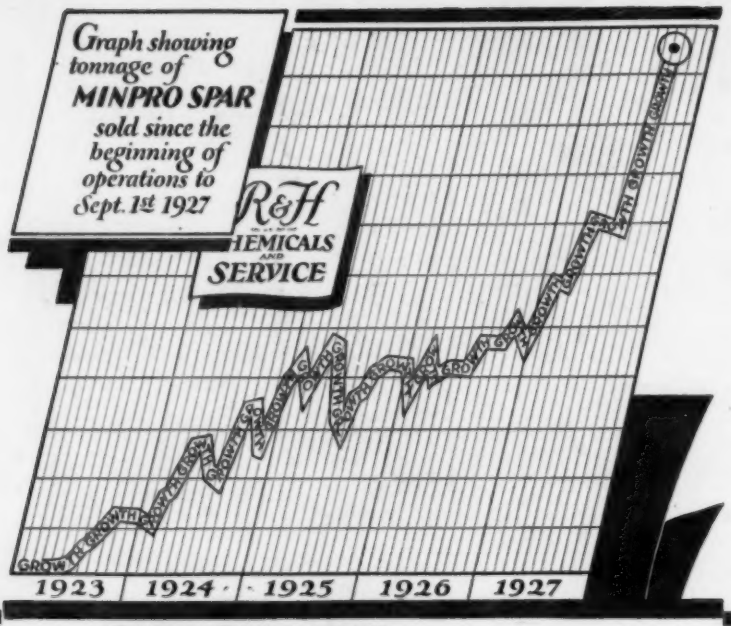

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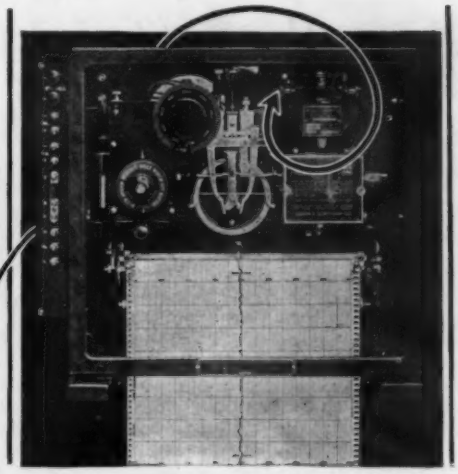

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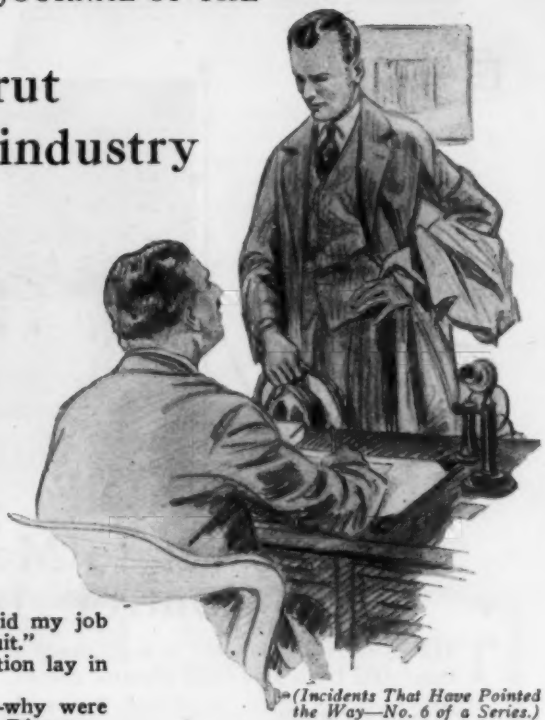

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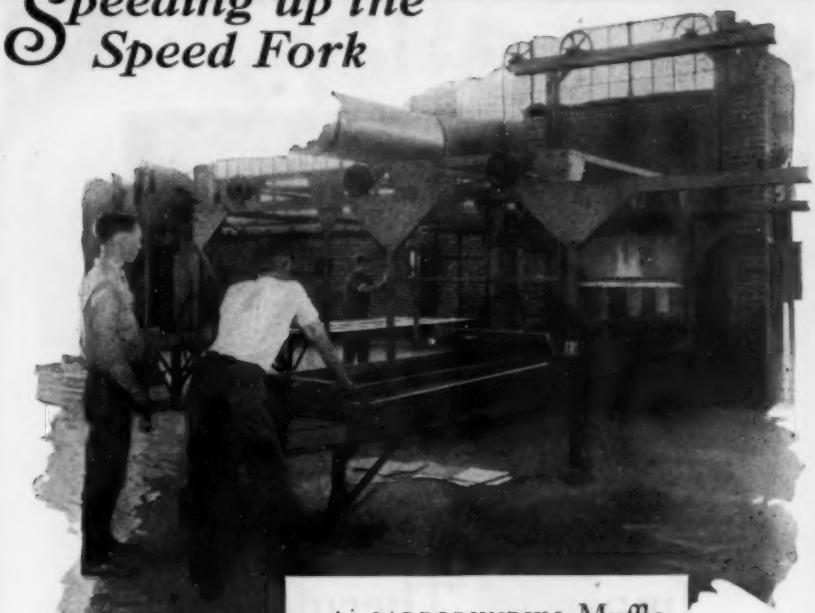

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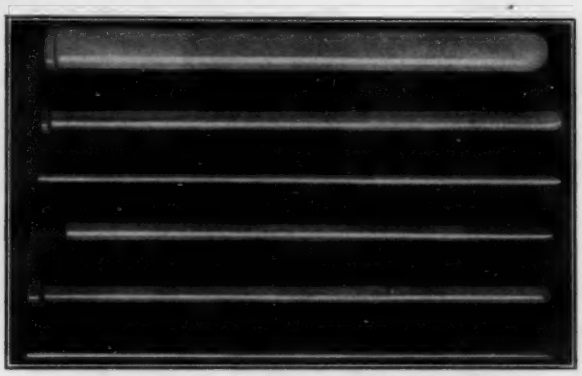

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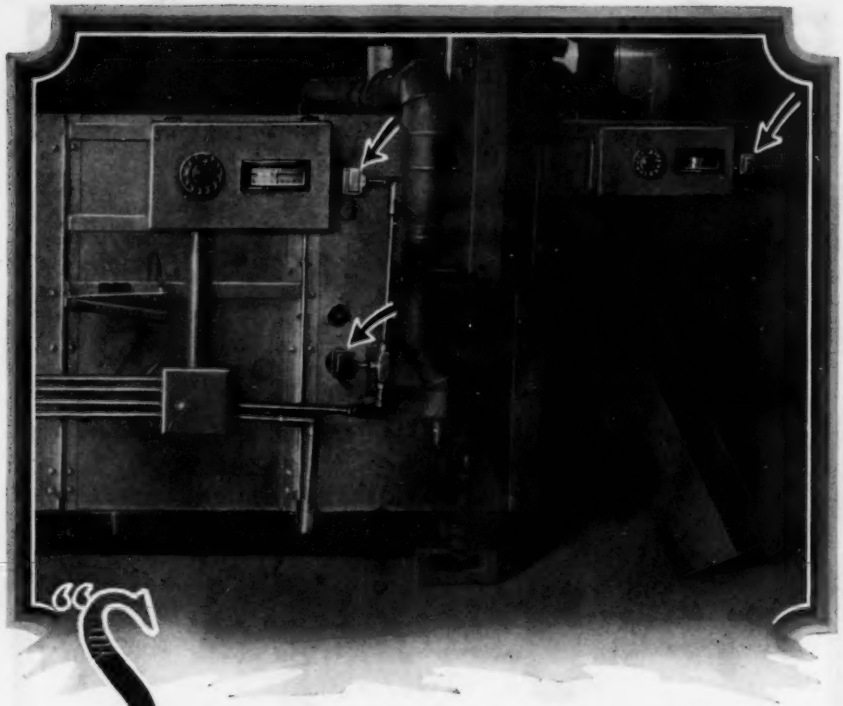

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for the

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Ceramic Abstracts

Bulletin

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LETTER OF TRANSMITTAL

To the Board of Trustees
AMERICAN CERAMIC SOCIETY

Your Committee on Standards herewith submits for your approval, a collection of Standard Definitions, Specifications, Tests, and Descriptions of Apparatus, together with other material which in our judgment will add to the value and usefulness of a Book of Standards of the AMERICAN CERAMIC SOCIETY.

The material marked Standard has been so authorized by the SOCIETY and that marked Tentative has been approved by the Committee on Standards. The other material included is without official recognition by the SOCIETY but it is either standard or tentative by some other organization and is included only where the AMERICAN CERAMIC SOCIETY has no standard. It may be approved or removed later as the SOCIETY may elect.

The Committee desires to acknowledge here its obligation to many other members of the SOCIETY who have assisted in the assembling of this material and especially to preceding committees on Standards who laid the foundation for this work.

Respectfully submitted,
COMMITTEE ON STANDARDS 1927–28
ARTHUR S. WATTS, *Chairman*

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I. GENERAL

1. ETYMOLOGY OF THE WORD "CERAMIC"[1]

W. A. OLDFATHER: *Ceramic* is a transliteration from the Greek adjective *Keramikos* which is derived from *keramos*, a general term designating the product of the potters' art. Now *keramos* is used of articles made exclusively or ordinarily out of clay by the process of firing.

E. W. WASHBURN, H. RIES, AND A. L. DAY: *Keramos* is related to an older Sanskrit root meaning "to fire" and as used by the Greeks its primary meaning was "fired stuff," that is, the fundamental idea in the word was that of a product obtained through action of fire. It was the process rather than the materials themselves which was the predominant element in meaning and usage by the Greeks.

The ceramic industries are those which manufacture products by the action of heat on materials of an earthy nature in which the oxide of silicon and the compounds thereof (the silicates) predominate.

See also W. A. Oldfather, *Jour. Amer. Ceram. Soc.*, **9** [9], 633 (1926) in proof that the derivative of *keramos*, *kerameus*, applies to a worker in glass.

2. INTERNATIONAL ATOMIC WEIGHTS[2]

Name	Symbol	O=16 M	Name	Symbol	O=16 M
Aluminum	Al	26.97	**Fluorine**	F	19.00
Antimony	Sb	121.77	Gadolinium	Gd	157.26
Argon	(An)	39.91	Gallium	Ga	69.72
Arsenic	As	74.96	Germanium	Ge	72.60
Barium	Ba	137.37	Glucinium	Gl	9.12
{Beryllium	Be	9.2	**Gold**	Au	197.2
{Glucinium	Gl	9.2	Hafnium (Celtium)	Hf	178.6
Bismuth	Bi	209.0	Helium	He	4.00
Boron	B	10.82	Holmium	Ho	163.4
Bromine	Br	79.916	**Hydrogen**	H	1.008
Cadmium	Cd	112.41	Illinium	Il	
Caesium	Cs	132.81	Indium	In	114.8
Calcium	Ca	40.07	Iodine	I	126.932
Carbon	C	12.000	Iridium	Ir	193.1
Cerium	Ce	140.25	**Iron**	Fe	55.84
Chlorine	Cl	35.457	Krypton	Kr	82.9
Chromium	Cr	52.01	Lanthanum	La	138.90
Cobalt	Co	58.94	**Lead**	Pb	207.20
Columbium	Cb	93.1	Lithium	Li	6.940
Niobium	Nb	93.1	Lutecium	Lu	175.0
Copper	Cu	63.57	**Magnesium**	Mg	24.32
Dysprosium	Dy	162.52	**Manganese**	Mn	54.93
Erbium	Er	167.7	**Mercury**	Hg	200.61
Europium	Eu	152.0	Molybdenum	Mo	96.0

[1] See p. 526, *Jour. Amer. Ceram. Soc.*, **3**, 7 (1920), Rept. Comm. on Definition of "Ceramics." See also *Bull. Amer. Ceram. Soc.*, **3** [4], 114 (1924).

[2] A. I. Andrews, Ceramic Tests and Calculations, p. 125. John Wiley & Sons, 1928. Also *Jour. Amer. Chem. Soc.*, **49**, 3 (1927).

Name	Symbol	O=16 M	Name	Symbol	O=16 M
Neodymium	Nd	144.27	Silver	Ag	107.880
Neon	Ne	20.2	Sodium	Na	22.997
Nickel	Ni	58.69	Strontium	Sr	87.63
Nitrogen	N	14.008	Sulphur	S	32.064
Osmium	Os	190.8	Tantalum	Ta	181.5
Oxygen	O	16.000	Tellurium	Te	127.5
Palladium	Pd	106.7	Terbium	Tb	159.2
Phosphorus	P	31.027	Thallium	Tl	204.39
Platinum	Pt	195.23	Thorium	Th	232.15
Potassium	K	39.096	Thulium	Tm	169.4
Praseodymium	Pr	140.92	Tin	Sn	118.70
Radium	Ra	225.95	Titanium	Ti	48.1
Radon	Rn	222.	Tungsten	W	184.0
Rhodium	Rh	102.91	Uranium	U	238.17
Rubidium	Rb	85.44	Vanadium	V	50.96
Ruthenium	Ru	101.7	Xenon	Xe	130.2
Samarium	Sm	150.43	Ytterbium (Neoytterbium)	Yb	173.6
Scandium	Sc	45.10	Yttrium	Y	88.9
Selenium	Se	79.2	Zinc	Zn	65.38
Silicon	Si	28.06	Zirconium	Zr	91.

3A. COMMON CERAMIC MINERALS, ETC., WITH TECHNICAL EQUIVALENTS

Name of material	Principal chemical composition	Formula
Albite	See feldspar	
Andalusite	Aluminum silicate	$Al_2O_3 \cdot SiO_2$
Anorthite	See feldspar	
Apatite	Tricalcium phosphate	$Ca_3(PO)_2$
Aragonite	See calcite	
Baddeleyite	Zirconium oxide	ZrO_2
Bauxite	Hydrated aluminum oxide	$Al_2O_3 \cdot 2H_2O$
Biotite	See mica	
Bone ash	Tricalcium phosphate	$Ca_3(PO)_2$
Borax	Sodium tetraborate	$N_2B_4O_7 \cdot 10H_2O$
Boric acid	Boric hydroxide	$B_2O_3 \cdot 3H_2O$
Calcite (aragonite, limestone, chalk, marble, whiting)	Calcium carbonate	$CaCO_3$
Chalk	See calcite	
Chromite	Ferrous chromate	$FeOCr_2O_3$
Colemanite	Calcium borate	$Ca_2B_6O_{11} \cdot 5H_2O$
Cristobalite	See flint	
Cryolite	Sodium aluminum fluoride	$AlF_3 \cdot 3NaF$
Cyanite	Aluminum silicate	$Al_2O_3 \cdot SiO_2$
Diaspore	Hydrated aluminum oxide	$Al_2O_3 \cdot H_2O$
Dolomite	Double carbonate of calcium and magnesium	$CaCO_3 \cdot MgCO_3$
Feldspar		
Albite (soda feldspar)	Sodium aluminum silicate	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$
Anorthite (lime feldspar)	Calcium aluminum silicate	$CaO \cdot Al_2O_3 \cdot 2SiO_2$
Orthoclase (potash feldspar)	Potassium aluminum silicate	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$
Flint, sand, quartz, ganister, tridymite, kieselguhr, tripoli, silica, cristobalite		SiO_2
Fluorspar (fluorite)	Calcium fluoride	CaF_2
"French chalk"	See talc	
Ganister	See flint	
Gibbsite	Hydrated aluminum oxide	$Al_2O_3 \cdot 3H_2O$
Granite (pegmatite)	Mixture of quartz, feldspar, and mica	
Gypsum (plaster of Paris)	Calcium sulphate	$CaSO_4 \cdot 2H_2O$

Name of material	Principal chemical composition	Formula
Hematite	Ferric oxide	Fe_2O_3
Ilmenite	Ferrous titanate	$FeO \cdot TiO_2$
Kaolinite (clay substance)	Hydrated silicate of aluminum	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$
Kieselguhr	See flint	
Lime	Calcium oxide	CaO
Limestone	See calcite	
Limonite	Hydrous ferric oxide	$2Fe_2O_3 \cdot 3H_2O$
Litharge	Lead monoxide	PbO
Magnesia	Magnesium oxide	MgO
Magnesite	Magnesium carbonate	$MgCO_3$
Magnetite	Ferrosoferric oxide	Fe_3O_4
Marble	See calcite	
Marl	Clay containing 4–15% of calcium carbonate	
Mica	Mixed hydrated aluminum silicates	
Muscovite (potash mica)	Silicate of aluminum and potassium	
Biotite (magnesia mica)	Silicate of aluminum and magnesium	
Mullite	Aluminum silicate	$3Al_2O_3 \cdot 2SiO_2$
Muscovite	See mica	
Orthoclase	See feldspar	
Pegmatite	See granite	
Pyrite (marcasite)	Iron sulphide	FeS_2
Pyrolusite	Manganese dioxide	MnO_2
Quartz	See flint	
Red lead	Lead tetroxide	Pb_3O_4
Rutile	Titanium oxide	TiO_2
Salt	Sodium chloride	$NaCl$
Sand	See flint	
Siderite	Ferrous carbonate	$FeCO_3$
Silica	See flint	
Sillimanite	Aluminum silicate	$Al_2O_3 \cdot SiO_2$
Soapstone	See talc	
Steatite	See talc	
Talc (steatite, soapstone, "French chak")	Hydrated or hydrous silicates of magnesium	$3MgO \cdot 4SiO_2 \cdot H_2O$
Tridymite	See flint	
Tripoli	See flint	
Whiting	See calcite	
Willemite	Silicate of zinc	$2ZnO \cdot SiO_2$
Witherite	Barium carbonate	$BaCO_3$
Wollastonite	Calcium silicate	$CaSiO_3$
Zircon	Zirconium silicate	ZrO_2SiO_2

3B. CERAMIC MATERIALS

Name of material	Formula	Mol. wt.	Equiv. wt.
Albite	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	524	524
Alumina	Al_2O_3	102	102
Aluminum hydroxide	$Al_2(OH)_6$	156	156
Aluminum sulphate	$Al_2(SO_4)_3$	342	342
Antimony oxide	Sb_2O_3	288	288
Arsenious oxide (white arsenic)	As_2O_3	198	198
Barium carbonate	$BaCO_3$	197	197
Barium chloride	$BaCl_2$	208	208
Barium chromate	$BaCrO_4$	253	$\begin{cases} RO \cdot 5R_2O_3 & 253 \\ 2RO \cdot R_2O_3 & 506 \end{cases}$
Barium hydroxide	$Ba(OH)_2$	171	171
Barium oxide	BaO	153	153
Barium sulphate	$BaSO_4$	233	233
Barytes	$BaSO_4$	233	233

Name of material	Formula	Mol. wt.	Equiv. wt.
Barium carbonate	$BaCO_3$	197	197
Bismuth oxide	Bi_2O_3	464	464
Bone ash	$Ca_3(PO_4)_2$	310	RO 103
Boracic acid	$B_2O_3 \cdot 3H_2O$	124	R_2O_3 124
Borax	$Na_2O2B_2O_3 \cdot 10H_2O$	382	$RO \cdot 2R_2O_3$ 382
Borax (melted)	$Na_2O \cdot 2B_2O_3$	202	$RO \cdot 2R_2O_3$ 202
Boric oxide	B_2O_3	70	70
Calcium borate (colemanite)	$2CaO \cdot 3B_2O_3 \cdot 5H_2O$	412	$RO \cdot 1.5R_2O_3$ 206
Calcium carbonate	$CaCO_3$	100	100
Calcium chloride	$CaCl_2$	111	111
Calcium fluoride	CaF_2	78	78
Calcium hydroxide	$Ca(OH)_2$	74	74
Calcium oxide	CaO	56	56
Calcium phosphate	$Ca_3(PO_4)_2$	310	RO 103
Calcium sulphate	$CaSO_4$	136	136
Celestite	$SrSO_4$	183	183
Cerium oxide	CeO_2	176	176
China clay	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	258	258
Chromium oxide	Cr_2O_3	152	152
Chromium sulphate	$Cr_2(SO_4)_3 \cdot 15H_2O$	662	662
Cobalt carbonate			
Cobalt chloride	$CoCl_2 \cdot 6H_2O$	238	238
Cobalt oxide (cobaltic)	Co_2O_3	166	RO 83
Cobalt oxide (cobalto-cobaltic) (black)	Co_3O_4	241	RO 80
Cobalt oxide (cobaltous)	CoO	75	75
nitrate	$Co(NO_3)_2 \cdot 6H_2O$	291	291
sulphate	$CoSO_4 \cdot 7H_2O$	280	280
Copperas	$FeSO_4 \cdot 7H_2O$	278	278
Copper carbonate	$CuCO_3$	124	124
Copper chloride	$CuCl_2 \cdot 2H_2O$	171	171
Copper oxide (cupric) (green)	CuO	80	80
Copper oxide (cuprous) (red)	Cu_2O	144	144
Copper sulphate	$CuSO_4$	160	160
Cornish stone (Cornwall)	Indefinite		
Crocus Martis	Impure Fe_2O_3		
Cryolite	$3NaF \cdot AlF_3$	210	$RO \cdot .33R_2O_3$ 140; $3RO \cdot R_2O_3$ 420
Dolomite	$CaCO_3 \cdot MgCO_3$	184	RO 92
Feldspar (potash)	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	556	556
Feldspar (soda)	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	524	524
Feldspar (lime)	$CaO \cdot Al_2O_3 \cdot 2SiO_2$	278	278
Ferric chloride	$FeCl_3 \cdot 6H_2O$	270.5	270.5
Ferric hydroxide	$Fe(OH)_3$	107	107
Ferric oxide	Fe_2O_3	160	160
Ferric sulphate	$Fe_2(SO_4)_3$	400	400
Ferrous carbonate	$FeCO_3$	116	116
Ferrous oxide	FeO	72	72
Ferrous sulphate	$FeSO_4 \cdot 7H_2O$	278	278
Ferroso-ferric oxide	Fe_3O_4	232	R_2O_3 155
Flint	SiO_2	60	60
Fluorspar	CaF_2	78	78
Gold chloride	$AuCl_3$	303.5	303.5
Gypsum	$CaSO_4 \cdot 2H_2O$	188	188
Heavy feldspar	$BaSO_4$	233	233
Kaolin (-ite)	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	258	258
Lead carbonate	$PbCO_3$	267	267
Lead carbonate (basic) (white lead)	$2PbCO_3 \cdot Pb(OH)_2$	775	RO 258
Lead chloride	$PbCl_2$	278	
Lead chromate	$PbCrO_4$	323	$RO \cdot .5R_2O_3$ 323; $2RO \cdot R_2O_3$ 646
Lead oxide (plumbic) (litharge)	PbO	223	223

Name of material	Formula	Mol. wt.	Equiv. wt.
Lead oxide (red) (minium)	Pb_3O_4	685	RO 228
Lime	CaO	56	56
Lithium carbonate	Li_2CO_3	74	74
Lithium oxide	Li_2O	30	30
Magnesium carbonate	$MgCO_3$	84	84
Magnesium chloride	$MgCl_2 \cdot 6H_2O$	203	203
Magnesium hydroxide	$Mg(OH)_2$	58	58
Magnesium oxide	MgO	40	40
Magnesium sulphate	$MgSO_4 \cdot 7H_2O$	246	246
Manganese carbonate	$MnCO_3$	115	115
Manganese oxide (greenish)	MnO	71	71
Manganese oxide (black)	MnO_2	87	87
Manganese oxide (brownish-black)	Mn_2O_3	158	RO 79
Manganese oxide (red)	Mn_3O_4	229	RO 76
Minium	Pb_3O_4	685	RO 228
Nickel oxide (nickelous) (green)	NiO	75	75
Nickel oxide (nickelic) (black)	Ni_2O_3	166	RO 83
Paris white	$CaCO_3$	100	100
Pearl ash	K_2CO_3	138	138
Plaster of Paris	$CaSO_4 \cdot {}^1/_2H_2O$	161	161
Pyrolusite	MnO_2	87	87
Potassium bichromate	$K_2Cr_2O_7$	294	$RO \cdot R_2O_3$ 294
Potassium carbonate	K_2CO_3	138	138
Potassium chromate	K_2CrO_4	194	$RO \cdot 5R_2O_3$ 194 $2RO \cdot R_2O_3$ 388
Potassium nitrate	KNO_3	101	
Potassium oxide	K_2O	94	94
Sodium biborate	$Na_2O \cdot 2B_2O_3 10H_2O$	382	$RO \cdot 2B_2O_3$ 382
Sodium bicarbonate	$NaHCO_3$	84	RO 168
Sodium carbonate (crystal)	$Na_2CO_3 10H_2O$	286	286
Sodium carbonate (fused)	Na_2CO_3	106	106
Sodium nitrate	$NaNO_3$	85	85
Sodium oxide	Na_2O	62	62
Sodium uranate	$Na_2U_2O_7 \cdot 6H_2O$	745	$RO \cdot 2RO_3$ 745 $.5RO \cdot RO_3$ 372
Strontium carbonate	$SrCO_3$	148	148
Strontium oxide	SrO	104	104
Silica	SiO_2	60	60
Tin oxide (stannous)	SnO	135	135
Tin oxide (stannic)	SnO_2	151	151
Titanium oxide	TiO_2	80	80
Uranium oxide	U_2O_3	525	525
Uranium oxide (yellow)	$Na_2U_2O_7 \cdot 6H_2O$	745	$RO \cdot 2RO_3$ 745 $.5RO \cdot RO_3$ 372
Witherite	$BaCO_3$	197	197
Whiting	$CaCO_3$	100	100
Zinc carbonate	$ZnCO_3$	125	125
Zinc oxide	ZnO	81	81
Zirconium oxide	ZrO_2	123	123

4. PYROMETRIC CONE-TEMPERATURE-TIME RELATION TABLE[1]

The temperatures in the following table, which have been determined under standardized and reproducible conditions (controlled

[1] Data from C. O. Fairchild and M. F. Peters Research, *Jour. Amer. Ceram. Soc.*, 9 [11], 738 (1926).

rate of heating in clean air) will apply with fair approximation for the cones when heated in kilns where the gases are normally oxidizing and free from sulphur oxides. If the cones show a visible hardening of the surface or a skin effect resulting from exposure to kiln gases containing insufficient oxygen, small corrections may be necessary. Such surface action is most frequently noticed with cones 015 to 01. In kilns fired with fuel containing appreciable amounts of sulphur, or where the ware gives off sulphur dioxide, the end points may be noticeably different from those given in the table.

END POINTS AND INTERVALS OF PYROMETRIC CONES (HEATED IN AIR)

(Rate of Heating)

Cone No.	20°C/hr. End point	150°C/hr. End point	20°C/hr. Bending interval	150°C/hr. Bending interval	20°C/hr. Cone interval	150°C/hr. Cone interval
022	585°C	605°C	45°C	55°C	10°C	10°C
021	595	615	45	45	30	35
020	625	650	30	25	5	10
019	630	660	30	20	40	60
018	670	720	30	30	50	50
017	720	770	30	30	15	25
016	735	795	35	55	35	10
015	770	805	30	45	25	25
014	795	830	45	40	30	30
013	825	860	45	50	15	15
012	840	875	50	85	35	30
011	875	905	65	65	15	−10
010	890	895	30	25	40	35
09	930	930	35	40	15	20
08	945	950	55	60	30	40
07	975	990	35	50	30	25
06	1005	1015	25	35	25	25
05	1030	1040	30	30	20	20
04	1050	1060	40	40	30	55
03	1080	1115	40	35	15	10
02	1095	1125	35	35	15	20
01	1110	1145	50	45	15	15
1	1125	1160	30	45	10	5
2	1135	1165	30	45	10	5
3	1145	1170	30	40	20	20
4	1165	1190	40	35	15	15
5	1180	1205	40	50	10	25
6	1190	1230	40	35	20	20
7	1210	1250	40	60	15	10
8	1225	1260	45	55	25	25
9	1250	1285	65	115	10	20
10	1260	1305	40	95	25	20
11	1285	1325	70	80	25	10
12	1310	1335	80	45	40	15
13	1350	1350	70	55	40	50
14	1390	1400	100	70	20	35
15	1410	1435	85	115	40	30
16	1450	1465	70	125	15	10
17	1465	1475	50–75?	125	20	15
18	1485	1490	90	85	30	30
19	1515	1520	100	70	5	10
20	1520	1530	—	60		50

END POINTS AND INTERVALS OF PYROMETRIC CONES (HEATED IN AIR) (*continued*)

Cone No.	(Rate of Heating) 20°C/hr. End point	150°C/hr. End point	20°C/hr. Bending interval	150°C/hr. Bending interval	20°C/hr. Cone interval	150°C/hr. Cone interval
23	In Arsem	1580		30		15
26	furnace at	1595		10		10
27	600°C	1605		15		10
28	per hr.	1615		10		25
29		1640		30		10
30		1650		25		30
31		1680		25		20
32		1700		15		45
33		1745		30		15
34	1755	1760		15		25
35	1775	1785		15		25
36	1810	1810		25		10
37	1830	1820		5		15
38	1850	1835		15		
39	1865					
40	1885					
41	1970					
42	2015					

Cones 23 to 38 heated at 100°C per hour

5. SYMBOLS FOR HEAT AND THERMODYNAMICS[1]

(A) Proposed Tentative American Standards

General Principles (1) In most cases the same symbol shall be used, regardless of systems of units. Thus v is specific volume, whether cc. per gram, cc. per mol, cu. ft. per lb., etc.

(2) In cases where more than one system of units is used in a discussion, a single symbol may be used, with addition of subscripts, superscripts, or indices to denote units other than the primary one, such as, p, p_t, p', p''. (Sometimes, however, capital and small letters may distinguish units. See paragraph 7, pages 342 to 344.)

(3) The same symbol should be used for a given concept, regardless of the number of special values which occur, and subscripts or superscripts should be used to designate them.

(4) Letter subscripts should be used to denote values under special conditions or at special states, such as,

C_p or c_p = specific heat at constant pressure
C_v or c_v = specific heat at constant volume
η_t or e_t = thermal efficiency
η_m or e_m = mechanical efficiency

[1] Scientific and Engineering Symbols and Abbreviations prepared by Sub-Committee on Symbols for Heat and Thermodynamics, Sectional Committee on Scientific and Engineering Symbols and Abbreviations, American Engineering Standards Committee. Sponsor Bodies: American Association for the Advancement of Science, American Institute of Electrical Engineers, American Society of Civil Engineers, Society for the Promotion of Engineering Education, The American Society of Mechanical Engineers, 29 West 39th Street New York, N. Y.

(5) Numerical subscripts should be used to denote values at designated points in an apparatus, process or cycle, such as,

p_1 = initial pressure
p_2 = final pressure
W = weight of a major item
$W_1, W_2, W_3, \ldots$ = weights of auxiliary items

(6) In order to increase the clarity of printed matter, which is practically always Roman, symbols alone or in equations should be printed in italics.

(7) Where possible, capital letters denote total quantities and small letters denote specific quantities, or quantities per unit. Thus,

S may be entropy of any weight, and
s may be entropy of unit weight

Sometimes, however, capital and small letters may distinguish units. Thus P may be total pressure and p partial pressure, or P may be lbs. per sq. ft. and p, lbs. per sq. in., or capitals may be values per mol, and small letters values per gram or per pound.

SYMBOLS

p or P = pressure, absolute or gage (force per unit area)
v = specific volume (volume per unit weight) $= 1/d$
d or v^{-1} or $1/v$ = density (weight or mass per unit volume)
C or c = specific heat
C_p or c_p = specific heat at constant pressure
C_v or c_v = specific heat at constant volume
k or κ = ratio of specific heats $= c_p/c_v$
Q = total quantity of fluid, water, gas, heat, light or electricity, total volume
q = flow rate, volume rate per unit of time, rate at which quantity of material passes through a machine, quantity of heat per unit time or unit weight
F = force or pressure on a total area, total load
A = atomic weight
A = area or surface
M = molecular weight (M is also used for moment of force)
m = mass $= W/g$
W = total weight
w = flow rate, weight rate, weight per unit of power or unit of time
w = quantity of work or mechanical energy per unit weight
W = total quantity of work or mechanical energy
P = power or horsepower, or energy per unit time
E = energy
J = mechanical equivalent of heat

A or J^{-1} or $1/J$ = heat equivalent of work

t = time

t or θ = thermometric temperature °F or °C (θ is preferably used only when t is used for time in the same discussion)

T = absolute temperature °F or °K

S or s or Φ or ϕ = entropy. Preferably, the capitals are used for any weight, and small letters for unit weight

U or u = internal or intrinsic energy. Preferably, the capital is used for any weight, and the small letter for unit weight

H or h = heat content, total heat or enthalpy $= u + (A)pv$. Preferably the capital is used for any weight and the small letter for unit weight

ψ = Helmholtz free energy or internal potential function $= u - Ts$

ξ or Z = Gibbs function or total potential function (sometimes called free energy) $= u + (A)pv - h - Ts$

Sub$_f$ = saturated liquid (fluid) at saturation pressure and temperature (liquid in contact with vapor)

Sub$_g$ = dry and saturated gas or vapor, at saturation pressure and temperature (vapor in contact with liquid)

This system, carried to a logical conclusion, requires also subscripts for liquid in contact with solid, solid in contact with liquid, solid in contact with vapor and vapor in contact with solid. However, these are not assigned at this time.

Sub$_c$ = conditions at critical point

Sub$_{fg}$ = vaporization values, or differences between values for vapor and liquid at saturation conditions

The other pairs of subscripts mentioned above, when assigned, might be used to denote values for fusion or melting, and sublimation

h_f = heat content, total heat, or enthalpy of saturated liquid, or heat of the liquid

h_g = heat content, total heat or enthalpy of dry, saturated vapor or gas

v_f, v_g, v_{fg}, etc. = various values for saturation and vaporization, according to above rules

p_f and T_f or p_g and T_g = saturation pressure and temperature

L or l or h_{fg} = heat of vaporization

L or l or h = with subscripts, may also be used to denote heat of fusion or heat of sublimation

R = gas constant in equation $pv = RT$

Two values are in customary use. The first is the universal constant, corresponding to v in the above equation as volume per mol (product of molecular weight and volume per unit weight). The second is the particular value for a given gas, corresponding to v as volume per unit weight. The second value is the first value divided by molecular weight M. If desired, a prime or a subscript may be used to distinguish between the two values.

C = concentration, amount of a particular constituent per given amount of mixture

x = quality of steam, pounds of dry steam per pound of mixture

n = exponent of polytropic expansion in expression $pv^n = \text{const.}$

p_m = mean effective pressure

G = specific gravity, referred to air for gases and to water for solids and liquids

g_o = standard value of acceleration of gravity = 980.665 cm./sec.^{2} = 32.1740 ft./sec.^{2}

g = local value of acceleration of gravity. For most engineering work the distinction between g and g_o is negligible and g may be used to represent either value without distinction

e or η = efficiency

N = revolutions per unit time

ω = angular velocity. (ω is also used in other lists for solid angle)

l, x, or s = length or distance

C or K = coefficients or constants

V = velocity

D = diameter

r = radius

μ = Joule Thomson coefficient $\left(\frac{dT}{dp}\right)_h$

μ = viscosity

$Y = \left(\frac{P_1}{P_2}\right)^{1-1/k} - 1$ = adiabatic factor

EXAMPLES OF USE OF DIFFERENT SYMBOLS BY DIFFERENT SUB-COMMITTEES TO REPRESENT THE SAME CONCEPT

Concept	Symbol	Concept	Symbol
Area	A	Revolutions per unit of time	N
(or surface)	A	(per minute)	n
	S		
	S	Velocity, angular	ω
Coefficients and constants	C or K		ω
	C	(roll)	p
		(pitch)	q
Density	W or γ	(yaw)	r
	d	Velocity, linear	v
(air)	ρ	(roll)	u
		(pitch)	v
Force	F	(yaw)	w
(longitudinal)	X		V
(lateral)	Y	(absolute)	V
(normal)	Z	(relative)	v
Moment of force	M		
(rolling)	L		
(pitching)	M		
(yawing)	N		

6. STANDARD SCALES FOR TESTING SIEVES

(A) U. S. Standard Sieve Series[1]

This sieve scale is essentially metric. The sieve having an opening of 1 mm. is the basic one, and the sieves above and below this in the series are related to it by using the fourth root of 2, or 1.1892 as the ratio of the width of one opening to the next smaller opening. In making selections from this series it is recommended that this be done on some systematic plan, as for example, the selection of every other sieve or of every fourth one in the series.

Meshes per lineal inch	Sieve number	Sieve opening (inches)	Sieve opening (millimeters)	Wire diameter (inches)	Wire diameter (millimeters)
2.58	2½	.315	8.00	.073	1.85
3.03	3	.265	6.73	.065	1.65
3.57	3½	.223	5.66	.057	1.45
4.22	4	.187	4.76	.050	1.27
4.98	5	.157	4.00	.044	1.12
5.81	6	.132	3.36	.040	1.02
6.80	7	.111	2.83	.036	.92
7.89	8	.0937	2.38	.0331	.84
9.21	10	.0787	2.00	.0299	.76
10.72	12	.0661	1.68	.0272	.69
12.58	14	.0555	1.41	.0240	.61
14.66	16	.0469	1.19	.0213	.54
17.15	18	.0394	1.00	.0189	.48
20.16	20	.0331	.84	.0165	.42
23.47	25	.0280	.71	.0146	.37
27.62	30	.0232	.59	.0130	.33
32.15	35	.0197	.50	.0114	.29
38.02	40	.0165	.42	.0098	.25
44.44	45	.0138	.35	.0087	.22
52.36	50	.0117	.297	.0074	.188
61.93	60	.0098	.250	.0064	.162
72.46	70	.0083	.210	.0055	.140
85.47	80	.0070	.177	.0047	.119
101.01	100	.0059	.149	.0040	.102
120.48	120	.0049	.125	.0034	.086
142.86	140	.0041	.105	.0029	.074
166.67	170	.0035	.088	.0025	.063
200.	200	.0029	.074	.0021	.053
238.10	230	.0024	.062	.0018	.046
270.26	270	.0021	.053	.0016	.041
323.	325	.0017	.044	.0014	.036

(B) The Tyler Standard Sieve Series[2]

This sieve scale has as its base an opening of .0029 inch which is the opening in 200-mesh .0021-inch wire, the standard sieve, as adopted by the U. S. Bureau of Standards, the openings increasing in the ratio of the square root of 2 or 1.414.

Where a closer sizing is required column 2 shows the Tyler Standard Screen Scale with intermediate sieves. In this series the sieve openings increase in the ratio of the fourth root of 2 or 1.189.

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[1] See *Bull. Amer. Ceram. Soc.*, **2** [7], 238–40 (1923).

[2] See *Jour. Amer. Ceram. Soc.*, **6** [3], 563–78 (1923); for Table see p. 346.

Tyler Standard Screen Scale √2 or 1.414 (openings in inches)	For closer sizing sieves from .0029 to 1.050-in. ratio $\sqrt[4]{2}$ or 1.189-	Openings (millimeters)	Openings (fractions of inch) (approx.)	Mesh (per lineal inch)	Diameter of wire (inches)
1.050	1.050	26.67	1	—	.148
—	.883	22.43	7/8	—	.135
.742	.742	18.85	3/4	—	.135
—	.624	15.85	5/8	—	.120
.525	.525	13.33	1/2	—	.105
—	.441	11.20	7/16	—	.105
.371	.371	9.423	3/8	—	.092
—	.312	7.925	5/16	2 1/2	.088
.263	.263	6.680	1/4	3	.070
—	.221	5.613	7/32	3 1/2	.065
.185	.185	4.699	3/16	4	.065
—	.156	3.962	5/32	5	.044
.131	.131	3.327	1/8	6	.036
—	.110	2.794	7/64	7	.0328
.093	.093	2.362	3/32	8	.032
—	.078	1.981	5/64	9	.033
.065	.065	1.651	1/16	10	.035
—	.055	1.397	—	12	.028
.046	.046	1.168	3/64	14	.025
—	.0390	.991	—	16	.0235
.0328	.0328	.833	1/32	20	.0172
—	.0276	.701	—	24	.0141
.0232	.0232	.589	—	28	.0125
—	.0195	.495	—	32	.0118
.0164	.0164	.417	1/64	35	.0122
—	.0138	.351	—	42	.0100
.0116	.0116	.295	—	48	.0092
—	.0097	.246	—	60	.0070
.0082	.0082	.208	—	65	.0072
—	.0069	.175	—	80	.0056
.0058	.0058	.147	—	100	.0042
—	.0049	.124	—	115	.0038
.0041	.0041	.104	—	150	.0026
—	.0035	.088	—	170	.0024
.0029	.0029	.074	—	200	.0021
		For coarser sizing—3- to 1 1/2-inch opening			
—	—	—	3	—	.807
—	—	—	2	—	.192
—	—	—	1 1/2	—	.148

II. STANDARD DEFINITIONS[1]

7. CLAY

An earthy or stony mineral aggregate consisting essentially of hydrous silicates and alumina, plastic when sufficiently pulverized and wetted, rigid when dry, and vitreous when fired at a sufficiently high temperature.

8. SURFACE CLAY

An unconsolidated, unstratified clay, occurring on the surface.

9. FIRE CLAY

A sedimentary clay of low flux content.

NOTE: It is usually associated with coal measures.

10. SHALE

A thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.

11. PLASTIC OR BOND FIRE CLAY

A fire clay of sufficient natural plasticity to bond nonplastic materials.

12. FLINT FIRE CLAY

A hard or flintlike fire clay occurring as an unstratified massive rock, practically devoid of natural plasticity and breaking with a concoidal fracture.

13. DIASPORE CLAY

A rock consisting essentially of diaspore bonded by fire clay.

14. NODULAR FIRE CLAY

A rock containing aluminous or ferruginous nodules bonded by fire clay.

NOTE: In some districts such clays are called "burley" or "burley flint" clay.

15. PYROMETRIC CONE EQUIVALENT (P.C.E.)

An index to the degree of fusion resulting in a cone of the material bending until the tip touches the plaque as a result of a definite heat treatment prescribed by the A.S.T.M., Serial Designation C24–20.

NOTE: The terms fusion, softening point, and melting point have heretofore been loosely used for "pyrometric cone equivalent."

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[1] Tentative Standards, A.S.T.M., 1927.

III. TENTATIVE DEFINITIONS

16. SPALLING[1]

Breaking or cracking of refractories to such an extent that fragments are separated, presenting newly exposed surfaces of the residual mass.

NOTE: The causes of spalling may be classified under three main headings: (1) thermal, (2) mechanical, and (3) structural.

THERMAL SPALLING
Factors related

To Service	To Refractories
Rapidity and range of thermal fluctuation; contamination by slags and fluxes; tightness of joints; previous vitrification	Degree and uniformity of reversible thermal expansion; heat transfer; elasticity; plastic flow

MECHANICAL SPALLING
Factors Related

To Service	To Refractories
Rapid heating of wet brick; abuse in removing clinker and slag; unequal and excessive stresses; pinching	Mechanical strength; toughness

STRUCTURAL SPALLING
Factors Related

To Service	To Refractories
Slags and fluxes; character of the material in joints; insulation of refractories; no provision for expansion; thin joints	Vitrification, shrinkage; nature of bond; structure; degree of firing; accuracy of shape

17. BRICK

A structural unit in the form of a rectangular prism (usually solid and 8 by $3\frac{3}{4}$ by $2\frac{1}{4}$ inches in size).

NOTE: In the present state of the art the term "brick," when used without a qualifying adjective, is generally understood to mean a structural unit of clay or shale formed while plastic and subsequently fired.

When substances other than clay or shale are employed, such as lime and sand, cement and sand, fire clay, adobe, etc., the term "brick" should be suitably qualified.

18. APPARENT SPECIFIC GRAVITY

Apparent specific gravity is the specific gravity of the water impermeable portion of the specimen, that is, solid material plus sealed pores or cavities. Apparent specific gravity is then the weight per unit of volume of water-impermeable portion of the specimen.

19. BULK SPECIFIC GRAVITY

Bulk specific gravity is the specific gravity of the composite bulk,

[1] Tentative Standards, A.S.T.M., 1927.

that is, solid material plus sealed pores or cavities, and water-permeable pores. Bulk specific gravity is therefore the weight per unit of exterior volume.

20. TRUE SPECIFIC GRAVITY

True specific gravity is the weight per volume of the solid material in which all sealed pores or cavities and all water-permeable pores have been obliterated by fine grinding.

21. HIGH HEAT DUTY BRICK[1]

(A) Clay Fire Brick

(Silica content less than 70%)

(1) The pyrometric cone equivalent of a clay fire brick for high heat duty shall not be lower than that of standard cone 31 (about 1680°C or 3056°F).

(2) When duplicate samples of clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of 1400°C (2552°F), maintained at this temperature for five hours, and cooled, they shall not show a contraction of more than 1.5% of the original length or an expansion of more than 1%.

(3) When a brick of this type softens at a temperature not below the softening point of standard cone 29 (about 1640°C or 2984°F) it may be tested according to classification (B) for siliceous clay fire brick without losing in standing if it passes the tests.

(B) Siliceous Clay Fire Brick

(Silica content 70% or over)

(1) The pyrometric cone equivalent of siliceous clay fire brick for high heat duty shall not be lower than that of standard cone 28 (about 1615°C or 2939°F).

(2) All siliceous clay fire brick for high heat duty shall be subjected to a load test in accordance with the requirements of the Standard Test for Refractory Materials under Load at High Temperatures (Serial Designation C16) A.S.T.M. The pressure to be applied upon the brick (placed on end) shall be 25 lb. per sq. in. and the maximum furnace temperature 1350°C (2462°F). The brick shall not show a contraction of more than 4% of the original length, nor an expansion of more than 1%.

(3) When duplicate samples of siliceous clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of

[1] Same as A.S.T.M. Standard C27–20, Tentative Revision 1927 to omit items (A2) and (B3). Cone temperatures corrected to agree with Fairchild-Peters data.

1400°C (2552°F), maintained at this temperature for five hours, and cooled, they shall not show a contraction of more than 1.5% of the original length or an expansion of more than 1%.

22. INTERMEDIATE HEAT DUTY BRICK

(1) The pyrometric cone equivalent of brick for intermediate heat duty shall not be lower than that of standard cone 28 (about 1615°C or 2939°F).

(2) When duplicate samples of brick for intermediate heat duty are heated uniformly in a suitable furnace to a temperature of 1350°C (2462°F), maintained at this temperature for five hours, and cooled, they shall not show a contraction of more than 1.5% of the original length nor an expansion of more than 1%.

23. MODERATE HEAT DUTY BRICK[1]

(1) The pyrometric cone equivalent of brick for moderate heat duty shall not be lower than that of standard cone 26 (about 1595°C or 2903°F).

(2) When duplicate samples of brick for moderate heat duty are heated uniformly in a suitable furnace to a temperature of 1290°C (2354°F), maintained at this temperature for five hours, and cooled, they shall not show a contraction of more than 1.5% of the original length or an expansion of more than 1%.

24. LOW HEAT DUTY BRICK[2]

(1) The pyrometric cone equivalent of brick for low heat duty shall not be lower than that of standard cone 19 (about 1520°C or 2768°F).

[1] Same as A.S.T.M. Standard C27–20. Tentative Revision 1927 to omit item (2). Cone temperatures corrected to agree with Fairchild-Peters data.

[2] Same as A.S.T.M. Standard C27–20. Tentative Revision 1927. Cone temperatures corrected to agree with Fairchild-Peters data.

IV. METHODS OF CHEMICAL ANALYSIS

25. BUREAU OF STANDARDS METHODS OF ANALYSIS FOR FIRED REFRACTORIES[1]

(A) Drying

Transfer a portion of the sample to a weighing bottle and dry in an oven, in which the temperature can be observed and regulated. The layer of sample in the weighing bottle should not be more than one-half centimeter deep. Dry for one hour at 105–110° C. Allow to cool and use this dry sample for all determinations.

(B) Solution of the Sample

Thoroughly mix 0.5 g. of the dried sample with 7 to 8 g. of sodium carbonate in a platinum crucible and cover the mixture with an additional gram of sodium carbonate. Gradually heat the covered crucible and its contents until the mass is molten and then apply the full heat of a Meker or Fischer burner for one hour. Cool, and dissolve the melt in a platinum dish in 20 cc. of 10% (by volume) C.P. hydrochloric acid. If there is any indication of undecomposed sample, filter the solution; ignite the paper in the same crucible as was used for the fusion; fuse the residue with a small amount of sodium carbonate; add the cooled melt to the original solution. (If sulphuric acid is preferred for the subsequent dehydration of silica, dissolve the sodium carbonate melt in 150 cc. of 10% [by volume] sulphuric acid.)

As previously stated, if silica is not to be determined, bauxite may be decomposed by the use of hydrofluoric, nitric, and sulphuric acids.

(C) Determination of Silica

Evaporate the solution of the melt to dryness and dehydrate in an oven at a temperature of 105–120°C for one-half hour. Take up the dry mass in 150cc. of dilute hydrochloric acid (5% by volume), heat until the salts are in solution and filter through a No. 40 Whatman or similar paper. Wash very thoroughly with dilute hydrochloric acid (5% by volume) and finally with hot water. It is very important that the silica be washed free from sodium salts. Test wash water for chlorides and sulphates. Evaporate the filtrate to dryness and repeat the dehydration and filtration. Ignite the two papers in a platinum crucible and finally blast (1200°C) until constant weight is obtained. The heating should be very gentle at first to avoid mechanical loss of very finely powdered silica, and the crucible must be tightly covered during the blasting.

[1] Also suggested for clays.

After constant weight has been obtained, carefully moisten the silica in the crucible and add a few drops of sulphuric acid (1:1) and 10cc. of hydrofluoric acid. Evaporate; carefully expel the sulphuric acid and again ignite to constant weight. The difference between the two weights is SiO_2. To this must be added the silica recovered from the iron, alumina, etc. (Described below).

(D) Determination of Alumina

Fuse the nonvolatile residue from the silica with a small quantity of alkali pyrosulphate; cool; take up melt in water and add it to the filtrate from the silica determination. Dilute this solution to 350cc., add a few drops of methyl red indicator, heat to boiling and add ammonium hydroxide until the red color just changes to a light yellow. Boil for 1 to 3 minutes and if the red color of the indicator reappears, discharge it by adding another drop of ammonium hydroxide. Filter through a No. 40 Whatman or similar paper and wash five times with hot 5% ammonium chloride solution. Return the precipitate to the beaker in which the precipitation was made by washing it off the paper with a strong jet of water, and then pour 50cc. of hot dilute hydrochloric acid (1:1) throughout the paper. After the acid treatment the paper must be thoroughly washed with hot water, and owing to the fact that a small amount of aluminum salts often remains in this paper, it should be observed and ignited with the alumina.

A simpler procedure consists in returning the paper and precipitate to the beaker in which the precipitation was made and mechanically stirring the paper to a pulp. The hot hydrochloric acid specified above is then added to the precipitate and pulp, digested a few minutes, and diluted to 350–400°C.

After the precipitate has been dissolved by either of the two methods described above, repeat the precipitation and washing as before. Do not *allow the precipitate to run dry* on the paper, but keep the paper filled or nearly filled with wash solution. At least 250cc. of wash solution should be used for each precipitate in the final washing. If the precipitate is large, dry it and the paper on a watch glass and then transfer it carefully to a platinum crucible, weighed with cover; ignite at a low temperature at first, and finally covered in a strong blast (1200°C). Cool in a desiccator and weigh quickly. Repeat the blasting and weighing until constant weight is obtained. The precipitate contains the Al_2O_3, Fe_2O_3, TiO_2, ZrO_2, P_2O_5, V_2O_5, and Cr_2O_3 which were present in the sample besides the SiO_2 which escaped the double dehydration. In order to arrive at the true weight of alumina it is necessary to determine the weights of the other substances as described below and subtract from the total weight. As the quantities of Fe_2O_3, TiO_2,

ZrO_2, P_2O_5, and CrO_3 are relatively small, this method of obtaining alumina (by difference) yields quite accurate results. An accuracy of 1 part in 200 is attainable in careful work.

(E) Recovery of Silica

Fuse the alumina and other oxides with alkali pyrosulphate, cool and dissolve the melt in 100cc. of 10% (by volume) sulphuric acid. Evaporate to incipient fumes of sulphuric acid; cool; add 150–200cc. of warm water, heat until the salts are in solution, filter off the small amount of silica, ignite and treat with hydrofluoric and sulphuric acids as previously described. Add this silica to that previously obtained.

(F) Determination of Phosphorus (P_2O_5) Chromium (Cr_2O_3) and Vanadium (V_2O_5)

Nearly neutralize the filtrate obtained in the silica recovery with sodium hydroxide and pour this solution slowly and with constant stirring into 150cc. of a 10% solution of sodium hydroxide containing 1.0g. of sodium peroxide. Digest on the steam bath for one hour, cool, and filter through a filter which has previously been treated with sodium hydroxide of the same strength. Reserve the precipitate for the determination of iron, titanium, and zirconium. This treatment of the paper will guard against coloring matter which might be extracted from the paper. Determine the chromium by comparison of the color with a standard solution of chromium under the same conditions. After the color comparison, acidify, add a very slight excess of ammonium hydroxide to the solution to precipitate the aluminum which will carry down any phosphorus and vanadium present. Do not use an indicator such as methyl red in this precipitation as its color may subsequently interfere with the determination of vanadium. Litmus is sufficiently sensitive, although phosphorus and vanadium may be lost if a large excess of ammonium hydroxide is added. The precipitation with ammonium hydroxide at this point is introduced to eliminate large quantities of sodium sulphate which would interfere with the subsequent precipitation of phosphorus. Filter, dissolve the precipitate in 100cc. of 10% (by volume) nitric acid, and add a few drops of hydrogen peroxide. If any color develops, compare with a standard vanadium solution under the same conditions.

After the vanadium has been determined by comparison of the color transfer the solution to a 300cc. Erlenmeyer flask, boil for one-half hour, add 15cc. of nitric acid (sp. gr. 1.42), adjust the volume to about 125cc., and add 40cc. of dilute ammonium hydroxide (sp. gr. 0.96) and 40cc. of molybdate reagent. Shake for ten minutes, allow to stand for one-half hour, filter, wash the flask and precipitate ten times with

a 1% solution of potassium nitrate, and titrate with standard alkali and acid, using the 23:1 ratio of alkali to phosphorus.

If it is preferred, the phosphorus may be determined gravimetrically by solution of the phosphomolybdate and precipitation by magnesia mixture.[1]

The reagents often contain phosphorus and a careful blank carried through all steps of the determination is essential. It is desirable that a known amount of aluminum corresponding to that in the regular analysis be added to the blank. Without alumina in the blank any phosphorus in the reagent would be lost in the precipitation with ammonium hydroxide while in the regular determination it would be carried down by the alumina present in the sample. The results for phosphorus and aluminum would then be correspondingly high.

(G) Iron, Titanium, and Zirconium

Dissolve the precipitate reserved for the determination of iron, titanium, and zirconium in 25cc. of hot dilute hydrochloric acid (1:2); dilute with water to a volume of 200cc.; heat nearly to boiling and saturate with hydrogen sulphide. Allow to cool and filter off platinum sulphide which may have separated, and wash with a 1% solution of sulphuric acid saturated with hydrogen sulphide. To the filtrate and washings add 4g. of tartaric acid and render the solution slightly ammoniacal. Gas with a rapid stream of hydrogen sulphide for 5 minutes; allow to settle; wash with a solution of ammonium sulphide containing 5g. of ammonium chloride per liter.

Dissolve the iron sulphide off the paper with hot dilute hydrochloric acid (1:1) to which has been added a little potassium chlorate, evaporate to dryness, take up in 25cc. of 5% by volume hydrochloric acid, reduce with stannous chloride, and titrate with permanganate as in the Zimmermann-Reinhardt method.

The filtrate from the ammonium sulphide-tartrate precipitation contains the titanium and zirconium. Acidify this solution with sulphuric acid, dilute to 200cc. and adjust the acidity to 10% (by volume). Precipitate the titanium and zirconium in the cold solution with cupferron, and wash with cold 10% (by volume) sulphuric acid. Carefully dry the precipitate; ignite; treat with hydrofluoric and sulphuric acids to eliminate silica, and weigh as TiO_2+ZrO_2. It is unnecessary to destroy tartaric acid preliminary to the precipitation with cupferron.

Fuse the precipitate of TiO_2 and ZrO_2 with a small amount of pyrosulphate, dissolve the melt in 50cc. of 10% (by volume) sulphuric

[1] Lundell and Hoffman, *Ind. Eng. Chem.*, 15, 44 and 171 (1923).

acid; add sufficient hydrogen peroxide to oxidize all of the titanium (an excess does no harm); add 0.5g. of diammonium phosphate, allow to stand at the side of the steam bath overnight, filter, wash with 5% ammonium nitrate, ignite and weigh as ZrP_2O_7. Calculate to ZrO_2 and subtract from the total weight of TiO_2+ZrO_2. In very accurate work the ZrP_2O_7 should be fused with a little pyrosulphate, the melt dissolved in 10% sulphuric acid as before, and the precipitation repeated.

(H) Calcium and Magnesium

For these determinations a new and larger sample should be used. Put into solution from 1.000 to 5.000g. of the sample by fusion with sodium carbonate or treatment with hydrofluoric, nitric, and sulphuric acids, as directed under "Solution of the Sample," p. 351. If the solution of the sample is accomplished by fusion with carbonate, silica must be eliminated. Nearly neutralize the solution with sodium hydroxide and pour slowly and with constant stirring into 150cc. of a 10% solution of sodium hydroxide containing 1.0g. of sodium carbonate. If the sample does not contain iron it is advisable to add about 0.01g. of iron to the solution of the sample before pouring it into the sodium hydroxide-carbonate solution. Digest on the steam bath for one-half hour; allow to cool; filter and wash a few times with dilute sodium hydroxide solution (5g. sodium hydroxide per liter).

Dissolve the precipitation in 25cc. of hot dilute hydrochloric acid (1:2) and in this solution precipitate the iron, titanium, etc., by addition of a slight excess of ammonium hydroxide using methyl red as indicator. Filter, redissolve the precipitate, and repeat the precipitation with ammonium hydroxide. If it seems desirable to determine iron, titanium, and zirconium on a large sample, the precipitate obtained may here be dissolved in hydrochloric acid and the iron, titanium, and zirconium determined as previously described. In the combined filtrates, precipitate the calcium as oxalate in slightly ammoniacal solution; filter and ignite the precipitate of calcium oxalate. Dissolve in a small amount of hydrochloric acid and repeat the precipitation of calcium in a volume of 50cc. Ignite and weigh as CaO.

Precipitate the magnesia in the combined filtrates from the calcium determination by the addition of 2g. of diammonium phosphate to the cold acid solution and then render ammoniacal while stirring. Add 10cc. of ammonium hydroxide in excess; allow to stand at least 12 hours; filter, redissolve in hydrochloric acid, and repeat the precipitation in a volume of 50cc. A few crystals of diammonium phosphate should be added to the acid solution before the second precipitation. Carefully ignite the precipitate and weigh as $Mg_2P_2O_7$.

(I) Alkalis

Alkalis are to be determined by the J. Lawrence Smith method.[1]

26. A.S.T.M. METHODS FOR REFRACTORY MATERIALS

(A) Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick[2]

It will be understood that the making of a complete silicate analysis is a difficult procedure requiring a wide knowledge of the chemistry involved in the operations, and a thorough training in carrying out the work. A skilled analyst of good training is therefore required to do the work.[3]

(B) General Refractories

(1) Grinding of Sample The sample shall be crushed in a hardened tool-steel mortar, using a pestle of the same sort. Fine grinding shall be done in an agate mortar, either by hand, or by a mechanical sample grinder of the McKenna, Carling, or similar type, so constructed as to prevent the introduction of impurity.

(2) Statement of Analysis Moisture shall be determined in the sample in its ordinary air-dried condition, and all other percentage compositions shall be calculated to a moisture-free basis. Whenever a sample is weighed out for any determination, a moisture determination shall also be made. If preferred, the sample may be dried in a weighing bottle, from which the required samples shall be weighed out.

(3) Checking Results In all cases, check determinations shall be made, and the results shall be redetermined if satisfactory checks are not obtained. It shall be considered satisfactory if the differences between check determinations do not exceed the following limits: (1) for silica or other constituent amounting to 30% or over, 0.3%; (2) for alumina or other constituent amounting to 10–30%, 0.2%; and (3) for any other constituent amounting to under 10%, 0.1%. These figures are stated in terms of the whole sample as 100%.

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[1] See Section 26 (D9) p. 360.

[2] Serial Designation C18–21. These methods are issued under the fixed designation C18; the final number indicates the year of original adoption as standard or, in the case of revision, the year of last revision. Issued as Tentative, 1917; adopted in Amended Form, 1920; revised, 1921.

[3] The descriptions here given cover the vital points of procedure, but frequent reference in regard to the details of the various manipulations must be made to U. S. Geol. Surv., *Bull.*, No. 422, "Analysis of Silicate and Carbonate Rocks," by W. F. Hillebrand; also, to "Treatise on the Ceramic Industries," Vol. I (1913), by J. W. Mellor and to similar publications.

(C) Solutions Required

(1) The acids referred to as concentrated shall be of approximately the following specific gravities:

Hydrochloric acid (HCL)	1.19
Sulphuric acid (H_2SO_4)	1.84
Nitric acid (HNO_3)	1.42

(2) Dissolve 1.5g. of ammonium carbonate in 50cc. of cold water.

(3) Dissolve 107g. of NH_4Cl in 1000cc. of warm water.

(4) Neutralize 20cc. of concentrated HNO_3 with NH_4OH and dilute to 1000cc. Test with litmus; the solution shall not be acid.

(5) Dissolve 1g. of ammonium oxalate in 50cc. of water, heating gently.

(6) The strength of the final standard titania solution shall be 1cc. = 0.0001g. TiO_2. To prepare the solution weigh out in a platinum crucible an amount of potassium titanium fluoride (K_2TiF_6) sufficient to make from $^1/_2$ to 1 liter of "stock solution" in which 1cc. = 0.001g. TiO_2. Evaporate several times with H_2SO_4 without taking to dryness, thus driving out all fluorine. Take up the residue with water containing enough H_2SO_4 to make at least 5% of the solution when finally diluted to the standard solution strength. To standardize the stock solution take out two 50-cc. portions; dilute, boil and precipitate with ammonia. Filter, wash with hot water until free from alkali, ignite, blast, and weigh. The duplicate should check very closely. From the weight of titania thus determined calculate the strength of the solution. The standard solution to be used is obtained from the stock solution by diluting until 1cc. = 0.0001g. (TiO_2).

(7) Dissolve about 0.4g. (a little less) of $KMnO_4$ in 1 liter of water and check against an iron solution of known purity and strength. Dilute the solution until 1cc. = 0.001g. Fe_2O_3.

NOTE: The ordinary chemical iron wire is not sufficiently pure for this use. If preferred the solution may be standardized against sodium oxalate, a pure form of which is prepared especially for such work by the U. S. Bureau of Standards, Washington, D. C.

(D) Methods

(1) Moisture To determine moisture, heat approximately 1g. of the sample at a temperature not under 105 or over 110°C, to constant weight.

(2) Ignition Loss To determine loss on ignition, heat about 1g. of the sample over a blast lamp or in an electric furnace at 900 to 1000°C, to constant weight. Ignition loss may be determined in the sample from which the moisture has been removed. The percentage of ignition loss is calculated to a moisture-free basis.

(3) Silica To determine silica, weigh out approximately 0.5g. of the sample and mix with 5g. of Na_2CO_3. Put a little Na_2CO_3 in the bottom of the crucible before introducing the mixture, and then cover the mixture with a little more Na_2CO_3. Fuse over a Meker burner or blast lamp until complete solution is obtained. Cool the fusion and as it solidifies, rotate the crucible to spread the mass up the side walls. Dissolve the fusion in about 100cc. of water in a platinum or porcelain evaporating dish. Add about 20cc. of concentrated HCl introducing it slowly by means of a pipette, keeping the dish covered with a watch glass. Evaporate to dryness and heat until the fumes of HCl are gone. Add about 5cc. of concentrated HCl and 30 to 40cc. of water. Warm on a water bath for 10 to 15 minutes and break up the lumps. Decant the clear liquid onto a filter paper and collect the filtrate in a 400-cc. beaker. Add more HCl and water to the evaporating dish, warm again, and decant. Repeat this a third time.

Finally transfer the contents of the dish to the filter paper. Wash with cold water until silver nitrate shows no chlorides to be left. Transfer the filtrate to the original evaporating dish, evaporate again to dryness, take up with a little HCl and water; transfer to a new filter paper and wash as before. Transfer both silica precipitates to a platinum crucible. Ignite carefully over a Bunsen flame until the filter paper is burned off, then blast for about 30 minutes; cool and weigh. Repeat blasting for 5 minutes, weigh again, and repeat until constant weight is obtained.

To the residue in the crucible add about 5cc. of water and 5 drops of H_2SO_4. Add HF drop by drop at first, and then slowly until the crucible is almost one-half filled. Warm on a hot plate until almost dry, add 2 or 3cc. more of HF and evaporate to dryness. Heat the crucible to bright redness and then blast for 5 minutes. Cool and weigh and repeat blasting to constant weight. The loss in weight from the original silica residue represents the actual silica content (SiO_2) except for that part of silica which is later recovered from alumina, etc. The residue from the HCl evaporation is left in the crucible and the total precipitate of alumina, etc., is added to this same crucible in which it is ignited and weighed.

(4) Alumina Regarding the determination of alumina, reference should be made to *Scientific Paper*, No. 286, U. S. Bureau of Standards by Dr. Blum on "Determination of Alumina as Oxide."

To determine alumina, to the filtrate from the silica determination, add about 10cc. of NH_4Cl solution and heat to boiling. Then add NH_4OH very slowly and with constant stirring until there is a slight excess. The NH_4OH must be free from CO_2. Filter hot and rapidly,

and wash four times by decantation with hot solution of ammonium nitrate. Careully wash the precipitate from the filter paper into a beaker, using hot water. Dissolve the precipitate in hot dilute HCl. Repeat the precipitation with NH_4Cl and NH_4OH. Decant four times as before, using hot ammonium nitrate. Transfer to the filter paper and wash with hot ammonium nitrate until the washings are free from chlorides when tested by silver nitrate. Evaporate the filtrate nearly to dryness, add a little NH_4OH and continue the evaporation. Keep the solution alkaline to coagulate any iron and aluminum hydroxides. Transfer the precipitate to a filter paper and wash thoroughly. Transfer the moist filter paper to the platinum crucible containing the residue from the silica. Burn off the filter paper and blast the precipitate. Repeat blasting and weighing to a constant weight.

(5) Iron Oxide To determine iron oxide, fuse the ignited alumina precipitate with about six times its weight of potassium pyrosulphate or potassium bisulphate. Avoid sputtering. Heat carefully to redness and continue heating until the residue is all dissolved. Cool. Dissolve in warm water and add about 10cc. of dilute H_2SO_4 (1:5). Evaporate to a small volume. Then heat to a higher temperature until copious fumes of H_2SO_4 are evolved. Sufficient H_2SO_4 should be present to form a pasty mass when cooled. Take up with water, filter off, wash, ignite, and weigh the silica as before and evaporate with HF as before. The loss in weight is extra silica to be added to the original silica determination and subtracted from the alumina. Fuse the residue with a little potassium pyrosulphate or potassium bisulphate, and add the solution of this cake to the main solution. Transfer the total filtrate to a 250-cc. graduated flask and dilute to 250cc. mixing thoroughly. Draw off 50cc. of this solution and reserve for titania determination. Pass the remaining 200cc. through a Jones reductor, or otherwise reduce the solution with pure zinc and H_2SO_4. To the solution add 3cc. of 10% $CuSO_4$ solution and titrate with standard $KMnO_4$ solution (1cc. equivalent to 0.001g. Fe_2O_3), until a faint pink tinge is seen. If Jones reductor or similar apparatus is used, subtract the $KMnO_4$ equivalent, which has previously been determined on blank samples run through the apparatus. From the result, calculate the iron as Fe_2O_3.

(6) Titania To determine titania, place in a small Nessler tube the 50cc. of filtrate previously set aside for titania determination, and fill the tube up to the graduation mark. Add 1cc. of H_2O_2 (free from fluorine) and shake well. The color of this solution is now compared in any standard color comparator with the color of a known standard solution, preferably of such strength that 1cc. equals 0.0001g. of titanium dioxide (TiO_2). To make the comparison, put 10cc. of this

standard solution into a second small Nessler tube and dilute with water from a burette until the color is matched. Note the amount of water added and calculate the percentage of TiO_2 in the sample.

(7) Lime To determine lime, evaporate the filtrate from the alumina precipitation to about 250cc. While still boiling add about 5cc. of acetic acid. Meanwhile, dissolve about 1g. of oxalic acid in a little hot water and add to the solution. In about 5 minutes add a slight excess of NH_4OH and boil until precipitation is complete. Cool thoroughly and filter. Wash three times by decantation with dilute NH_4OH (1:10) or a 1% solution of ammonium oxalate. Dissolve the precipitate by adding about 50cc. of dilute HNO_3 (1:5). Again add a slight excess of NH_4OH and a few drops of oxalic-acid solution. Boil well and let stand a couple of hours to cool. Filter and wash as before. Transfer the precipitate to a platinum crucible, carefully burn off the paper and ignite over a blast lamp for about 10 minutes. Cool and weigh quickly. Repeat the blasting to constant weight. The increase in weight of crucible is calcium oxide.

(8) Magnesia To determine magnesia, add to the filtrate from lime precipitation about 2g. of sodium-ammonium-phosphate dissolved in 15cc. of water. Stir vigorously and while stirring add drop by drop about one-third of the volume of the solution of NH_4OH. Let stand 12 to 24 hours. Filter and wash the precipitate with dilute NH_4OH (1:10). Discard the filtrate. Wash the precipitate until the washings show no discoloration when tested with silver nitrate. Redissolve the precipitate in warm dilute HNO_3 (1:5), using about 50cc., and collect in a beaker. Precipitate and wash as before. Collect the precipitate on a Gooch asbestos crucible. Dry slowly and then heat over a Meker burner for about 10 minutes; cool and weigh. Re-ignite to constant weight.

NOTE: The $Mg_2P_2O_7$ is never pure, being contaminated by small amounts of calcium, barium, aluminum, iron, manganese, etc., but in the analysis of refractories this error is negligible, and correction for these impurities is not required unless previously agreed upon.

(9) Alkalis To determine alkalis, the J. Lawrence Smith method shall be used. Weigh out about 0.5g. of the sample and mix well with 0.5g. of NH_4Cl and 3g. of $CaCO_3$. Transfer to a platinum crucible, placing about 0.5g. of $CaCO_3$ in the bottom of the crucible and a similar amount over the top of the mixture. Heat gently over a low flame for about 15 minutes to volatilize NH_4Cl. Then raise the temperature until the lower three-quarters of the crucible is dull red. Hold this temperature for about one hour. Cool, take up with about 50cc. of water and heat over a water bath, adding water to replace that lost by evaporation. Break up any lumps with a small pestle. Decant the

clear liquid through a filter paper and wash four times by decantation. Then transfer the residue to the filter. Wash until silver nitrate shows only a very faint turbidity. To the filtrate add NH_4OH and ammonium carbonate and heat to boiling. Filter and again digest the precipitate with NH_4OH and ammonium carbonate. Filter and allow the filtrate to collect with the previous filtrate, then evaporate to dryness in a platinum or porcelain dish. Remove ammonium salts by gentle ignition in a moving flame. Treat with water and remove the last trace of lime by adding ammonium oxalate to the boiling solution and let stand over night. Filter, evaporate to dryness, ignite gently and allow to cool. Then moisten the residue with HCl, evaporate again to dryness, ignite gently and weigh. Dissolve in water. Ignite and weigh any insoluble residue, deducting this from the alkali chlorides.

Dilute the solution of the mixed chlorides and add hydrochloroplatinic acid in amount equal to 0.3cc. more than would be necessary if all chlorides were present as NaCl. Evaporate to a syrupy consistency. Cool and treat with a few cubic centimeters of 80% ethyl alcohol. Stir and decant through a weighed Gooch crucible. Treat again with 80% alcohol and decant. Repeat washing and decantation until the alcohol leaving the Gooch crucible is colorless and the precipitate appears golden yellow, not orange. Transfer the precipitate to the Gooch crucible, wash with 80% alcohol about six times, and dry at 130°C to constant weight. This residue is potassium chloroplatinate.

The oxides are calculated as follows:

Weight of potassium chloroplatinate $\times 0.3068 = KCl$
Weight of potassium chloroplatinate $\times 0.1941 = K_2O$
Total chlorides $- KCl = NaCl$
$NaCl \times 0.5303 = Na_2O$

(E) Chrome Ores and Chrome Brick

(1) Sampling The sample shall be secured after the manner of any of the approved methods of sampling. If from ores or chrome-bearing refractories, it shall not be less than 10 lb. in small nut-size particles when sent to the laboratory. If from chrome brick, the sample shall consist of a small portion from the interior of from 15 to 25 bricks. This 10-pound sample shall be crushed to pass a No. 20 sieve[1] and quartered until a sample of 100g. is secured, which shall be ground to pass a No. 100 sieve.[1] From this portion, a smaller working sample shall be quartered and ground in an agate mortar to a very nearly gritless powder. In the case of hard-fired brick or hard lump chrome ore the very fine grinding assists materially in solution of the sample.

(2) Method Dry the fine, ground powder at 110°C for not less than one hour. Cool in desiccator. Fuse 0.5g. of the

[1] See 6(A) U.S. Standard Sieve Series (p. 345).

thoroughly dried sample in approximately 10g. of fused potassium bisulphate in a platinum crucible. The usual cautions of a bisulphate fusion should be observed: that is, the flame turned very low so that the bisulphate just melts, increasing the flame so that the bisulphate remains in a liquid condition, very gradually increasing until the crucible reaches a dull red heat. The object of the slow heating is to retain the sulphuric acid, which is the effective part of the flux. The most refractory ores should be thoroughly fused in $1\frac{1}{2}$ to 2 hours. Remove the crucible from the burner and allow to cool in the air. The bisulphate melt will shrink from the crucible and may be removed easily in one cake. Dissolve the fusion in 200cc. hot HCl (1:1), boiling until the solution acquires a clear, bright green color. Transfer the solution to a porcelain evaporating dish and evaporate to dryness on a water bath. Bake at exactly 120°C until free from hydrochloric acid fumes. Moisten with hot HCl (1:1), evaporate on water bath and bake a second time at 120°C. Dissolve in 200cc. hot dilute HCl (1:1), and filter out the silica. Ignite and weigh the silica in a platinum crucible. Add two drops concentrated H_2SO_4 and sufficient HF to remove all silica. Evaporate, ignite, and weigh. The difference gives the amount of silica present in the sample. Should there be any appreciable residue left in the crucible it should be fused with a small amount of fused $KHSO_4$ and added to the filtrate from the silica.

Dilute the filtrate from the silica to about 500cc. and precipitate iron, aluminum, chromium, and titanium, if present, with NH_4OH, using care to have not more than two drops of NH_4OH in excess in order to avoid solution of chromium and aluminum hydroxide in the alkaline solution. On account of the relatively large amount of magnesium that is usually present in chrome ores and chrome brick it is advisable to dissolve the precipitate in hot dilute HCl and precipitate a second time. Filter out the combined hydroxides and dissolve them on the filter paper with HNO_3, catching the solution in a porcelain casserole. Add a few crystals of $KClO_3$ and evaporate the nitric solution, adding a crystal of $KClO_3$ from time to time until the chromium is completely oxidized, which is indicated by a change from a dull green to a brilliant orange color. Dilute this solution with hot water and again precipitate with NH_4OH, filtering as before. The filtrate contains a large percentage of the chromium, while the residue on the filter consists of iron and aluminum hydroxides and titanium, if present. Repeat the oxidation two or three times until the filtrate from the iron and aluminum hydroxide precipitation shows no further traces of chromium. Concentrate and combine the filtrates containing chromium to ap-approximately 500cc. Add H_2SO_3 until the liquid changes from a bright orange to a brilliant green color and heat to boiling. Add NH_4OH

to precipitate chromium as hydroxide, having not more than two drops in excess, as stated above. Filter, wash well with hot water, ignite and weigh as Cr_2O_3. The iron and aluminum and titanium hydroxides are ignited and weighed in a platinum crucible. Fuse the combined oxides with a small amount of $KHSO_4$, following the same precautions as mentioned above. Dissolve the fusion in dilute H_2SO_4, reduce with H_2S and titrate the iron with standard permanganate solution. Determine the titanium present by the colorimetric method, as described in Section 26 (D6) p. 359. Subtract the combined amounts of Fe_2O_3 and TiO_2 from the total weight of the three oxides and thus determine Al_2O_3. If titanium is absent, reduce the iron with metallic zinc and titrate with K_2MnO_4, which is a little quicker method than the H_2S reduction.

To the combined filtrates from the precipitations of iron aluminum, chromium, and titanium hydroxides add bromine, allow to stand for a few minutes and then add sufficient NH_4OH to precipitate the manganese hydroxide. Boil to concentrate the manganese hydroxide if any be present. Filter, ignite, and weigh as Mn_3O_4. In the filtrate from the manganese add NH_4OH and $(NH_4)_2C_2O_4$. Heat to boiling and when the calcium oxide has settled, filter with the usual precautions. The calcium oxide may be determined by ignition or by the volumetric method. (Refer to the determination of calcium oxide as described in Section 26 (D8) p. 360.

Evaporate the filtrate from the calcium oxalate to dryness with HNO_3 to remove the excess of ammonium salts. Dissolve the residue in hot water, filter, allow to cool and determine MgO as described in Section 26 (D8) p. 360.

Determine alkalis by the J. Lawrence Smith Method, as described in Section 26 (D9) p. 360.

(F) Rapid Routine Method for the Analysis of Chrome Brick and Chrome Ore

(1) Rapid Routine Method The sample shall be secured after the manner of any of the approved methods of sampling. If from ores or chrome-bearing refractories it shall not be less than 10 pounds in small nut-sized particles when sent to the laboratory. If from chrome brick, the sample shall consist of a small portion from the interior of from 15 or 25 bricks. This 10-lb. sample shall be crushed to pass a No. 20 sieve[1] and quartered, until a 4 ounce sample is secured, which shall be ground to pass a No. 100 sieve.[1] From this portion a smaller working sample shall be quartered and

[1] For detailed specifications for these sieves, see the Standard Specifications for Sieves for Testing Purposes (Serial Designation E11) of the A.S.T.M., see p. 917.

ground in an agate mortar to a very nearly gritless powder. In the case of hard fired brick or hard lump chrome ore the very fine grinding assists materially in solution of the sample. Dry the fine, ground powder at 110°C for not less than 1 hour. Cool in desiccator.

(2) Chromium Fuse 0.5g. of the sample in 8 to 10g. of sodium peroxide in a nickel or porcelain crucible over a Bunsen burner, being careful not to heat too strongly. When fused, leach out with cold water, boil 15 minutes to decompose any sodium peroxide. Cool and add 100cc. of H_2SO_4 (1:1). Cool to tap-water temperature and titrate with ferrous ammonium sulphate and potassium permanganate. Time: 30 to 45 minutes.

(3) Silica and Iron Fuse 0.5g. of the sample in a nickel crucible over a Bunsen burner. Leach out with cold water, make acid with HCl and evaporate to dryness. Take up with 200cc. water and add 10cc. HCl. Filter off silica and wash well with hot water and hot dilute HCl. For high silica a second evaporation is necessary. The filtrate or combined filtrate is made alkaline with sodium hydroxide and about 5cc. of bromine added. The mass is allowed to digest for ½ hour on a steam bath. This oxidizes the iron and chromium, precipitates the iron, and dissolves the chromium and aluminum. After precipitating the iron twice it is filtered off on an asbestos plug and washed well with hot water. This precipitate of iron may be dissolved off the plug with hot HCl (1:1) and determined by the stannous chloride reduction and permanganate method.

A blank should be run in conjunction with this method and deductions made when necessary to determine the purity of the chemicals used.

27. TENTATIVE METHODS OF ANALYSIS OF GLASS

Method of analyzing soda-lime glass as outlined and adopted by the Glass Division Committee on Standards, AMERICAN CERAMIC SOCIETY, October 28, 1926, for acceptance as tentative standard method of routine analysis.

(A) Preparation of Sample

The sample is washed with distilled water (if necessary) and dried thoroughly with a clean cloth.

The cleaned and dried glass is chipped into an agate mortar and ground to pass 200-mesh. All of the sample is ground if the glass does not appear homogeneous. The finely-ground glass is then placed in a clean bottle and tightly stoppered as it is very hygroscopic.

NOTE: The steel mortar was discarded by the Committee due to its possibilities of contamination.

NOTE: The sample may be sieved if the sieve is used for glass only and well cleaned by brushing and air.

(B) Fusion of the Sample

If the sample is fused immediately no ignition is necessary. Otherwise the ignition must be run and the analysis calculated back to a moisture free basis.

$$\text{Example: } \frac{SiO_2 \times 100}{100 - \text{moisture}} = SiO_2 \text{ in moisture free glass.}$$

A one-gram portion of the prepared sample is carefully and thoroughly mixed with 5 grams Na_2CO_3 in a platinum crucible of 30- to 40-cc. capacity. At first the crucible (covered) is heated over a small flame. The heat is gradually increased until a quiet and perfectly clear fusion is obtained. At no time should there be a violent reaction. The flame should be directed against the bottom and sides at an angle and should not envelop the whole crucible.

When fusion is complete, the flame is removed and the cake allowed to solidify in a thin layer around the sides and bottom of the crucible. This effect may be obtained by seizing the crucible at the top with a pair of tongs and using a gentle gyratory motion.

When cool, the cake is loosened by gentle pressure on the sides of the crucible or by applying a small flame to melt a thin layer next to the crucible when the cake may be easily removed.

NOTE: According to Dittrich, potassium salts are more prone to pass into the precipitates than sodium and a fusion with the double salts is not as advisable as one with Na_2CO_3. The high melting point of Na_2CO_3 is also an aid to complete fusion.

The fusion may be made in an electric muffle, but is not as quick as the Bunsen burner, as the heat is slower of regulation.

(C) Silica

The fusion is transferred to a platinum dish, porcelain casserole, or Pyrex beaker of 150- to 400-cc. capacity with hot H_2O, making sure that the transfer is complete. This may be done with 75 to 100cc. H_2O. Cover with a watch glass and place on the steam bath till disintegration is complete. This may be aided with a blunt glass rod, breaking up all the large lumps. After disintegration is complete HCl is added in excess, being careful that the reaction is not too violent and that the dish is tightly covered. When the reaction is complete remove the cover and wash into the dish with H_2O. Wash down the sides of the dish and place uncovered on the steam bath and evaporate to apparent dryness.

NOTE: A platinum dish is preferred, since porcelain and Pyrex are attacked by the silicic acid of the solution.

NOTE: Water is added to the melt before adding HCl as it affects the precipitate in such a way as to make it break up easily and facilitates better washing, as it is less likely to contain occluded soda.

NOTE: There is no need of elaborate baking after the first evaporation as the baking affects the SiO_2 and the bulk of this is already taken down anyway. Refinement comes after the second evaporation.

Moisten the dry mass with HCl (1:1) and add 50 to 100cc. hot H_2O. Digest on the steam bath for 10 minutes and decant through the filter. Add 50cc. hot 1% HCl, break up any large lumps with a blunt stirring rod and decant again. Transfer the precipitate to the filter, police the beaker with hot 1% HCl, and wash the precipitate four times with hot H_2O.

Evaporate the filtrate to apparent dryness on the steam bath and bake at not more than 110°C for 1 hour to dehydrate the silica. Moisten the dry mass with hot HCl 1% and add 50cc. hot H_2O. Digest on the steam bath for 10 minutes and filter into a 400-cc. beaker. Police the beaker with hot HCl, 1%, and wash the precipitate four times with hot H_2O.

Place the combined precipitates in a platinum crucible, dry thoroughly, and burn off the papers without allowing to burst into flame. Blast for 15 minutes at 1200°C. Weigh and blast again at 1200°C to constant weight. Moisten the contents of the crucible with H_2O, add 3 drops H_2SO_4 and fill the crucible with HF. Evaporate to dryness and blast for a few minutes at 1200°C. The loss in weight is SiO_2. Report as SiO_2.

Fuse the residue left in the crucible with Na_2CO_3 and add to the filtrate.

NOTE: The time and temperature of baking was selected by the Committee in order to prevent the loss of silica by the formation of soluble magnesium silicates.

(D) Iron and Alumina

The combined filtrates from the silica are adjusted to a volume of approximately 200cc. One drop of HNO_3 is added as an oxidizing agent. The solution is then brought to a boil and a few drops of methyl red indicator added. Ammonium hydroxide is now added drop by drop till the solution turns distinctly yellow. The solution is then boiled for 3 or 4 minutes and the precipitate allowed to settle. A small paper, 7 cm., is used for the filtration.

Transfer the precipitate to the filter with hot NH_4NO_3 2%. Police the beaker and wash the precipitate with hot NH_4NO_3 2% till free from chlorides. The precipitate is ignited while moist in a platinum crucible at 1200°C to constant weight and weighed as the combined oxide of iron and alumina.

If it is desired to separate the two, the ignited residue is fused with 2 grams of fused $KHSO_4$. The fusion cake is dissolved in hot H_2O, 5cc. concentrated H_2SO_4 added and the iron reduced with H_2S and titrated with standard permanganate solution.

If the electrometric method is used, the fusion cake is dissolved in 1:1 HCl. Enough 1:1 HCl is added to bring the solution up to 150 cc.,

brought to a boil, reduced with stannous chloride, and titrated in the usual manner electrometrically.

The oxide of alumina is obtained by difference. In the ordinary analysis this separation is not carried out.

TiO_2 may be determined before or after the Fe_2O_3 determination by the colorimetric method and also subtracted from the alumina.

NOTE: The oxides of iron and alumina are slightly soluble in H_2O.

NOTE: Methyl red is preferred to methyl orange as its p_H value is better suited to this work.

(E) Lime

The filtrate from the iron and alumina determination is made slightly ammoniacal. The solution is brought to a boil and 25cc. saturated solution of ammonium oxalate added with vigorous stirring. Boil for 10 or 15 minutes and allow the precipitate to settle. Filter through a small filter paper. Police the beaker and wash the precipitate five times with $(NH_4)_2\ C_2O_4$ 1.5%. Wash once with hot H_2O to remove the excess $(NH_4)_2\ C_2O_4$. The precipitate is then washed into a beaker with hot H_2O through the punctured filter paper and dissolved in an excess of 25% H_2SO_4. The solution is made up to 75cc. with hot H_2O and is titrated with standard potassium permanganate to the first permanent faint pink color. The filter paper is placed on the inside of the beaker near the top and added to the solution near the end point. The calcium is calculated to CaO.

NOTE: Calcium oxalate is appreciably soluble in hot H_2O.

NOTE: If the filter paper is added directly to the solution, high results will be obtained.

(F) Magnesia

The filtrate from the calcia is made slightly acid with HCl and brought to a boil. The volume may range upward to 600cc. One-half gram microcosmic salt is added and the solution stirred thoroughly. One-ninth of the total volume of ammonium hydroxide is added, the solution stirred vigorously for 15 minutes and allowed to stand 6 hours, or over night before filtering. Frequent stirring and cooling will hasten the precipitation. The precipitate is filtered through a Gooch filter. Police the beaker and wash the precipitate five times with 5% NH_4OH. Dry in a drying oven or over a small flame before igniting. Ignite to constant weight at 1200°C. Calculate to MgO by using the factor .3621.

For greater accuracy the magnesia may be filtered through a filter paper, dissolved, and reprecipitated.

One precipitation is generally accurate enough for the routine method.

(G) Alkalis

In most routine analyses the alkalis are determined by difference. This throws all the error on the alkalis.

Example: $100-(SiO_2+Al_2O_3+Fe_2O_3+CaO+MgO)=$alkalis.

If a more accurate method is desired, the J. Lawrence Smith fusion method is recommended. (See Section 26 (D9) p. 360).

28. TENTATIVE METHOD FOR COMPLETE SAND ANALYSIS

(A) Preparation of the Sample

The sample may be a well-mixed unground portion or it may be ground in an agate mortar.

(B) Solution of the Sample

Weigh out a 10-g. sample and place it in a platinum dish of suitable size; 250cc. is recommended. Moisten the sample with water and add 2cc. concentrated sulphuric acid. Fill the platinum dish two-thirds full with concentrated hydrofluoric acid and evaporate on the sand bath, or if so desired on the hot plate, with an asbestos board beneath, to a volume of about 50cc. Care must be taken to avoid mechanical losses. Examine the contents of the dish and if complete solution of the sample has not taken place, add more hydrofluoric acid and evaporate again. When complete solution of the sample has been accomplished evaporate to copious fumes of SO_3, add 1 or 2 drops of fuming nitric acid to oxidize any organic matter. Cool the solution, dilute to about 100cc., filter, and transfer any residue left in the platinum dish to the filter. Wash the filter 5 times with hot water, place in a covered platinum crucible, dry and ignite until the filter paper has entirely burned off. Cool the crucible, add about 2 grams of sodium carbonate and fuse over a Meker burner or its equivalent. Cool the crucible, dissolve the melt with dilute hydrochloric acid and hot water in a small covered beaker. If a residue still remains after this treatment, filter into the main solution and wash 4 times with hot water. Dry and ignite the filter in a covered platinum crucible and fuse with one gram of potassium pyrosulphate. Dissolve the melt in dilute hydrochloric acid and hot water and add to the main solution.

Evaporate the total solution to a small volume and transfer to a platinum dish. Add 5cc. of concentrated hydrofluoric acid, evaporate to fumes of sulphuric acid, cool, wash down the sides of the dish with hot water, and again evaporate. Cool, add 50cc. of water and allow to stand 5 minutes. If the solution is not clear, filter and wash the residue 6 times with hot water.

(C) R_2O_3

Heat the filtrate from "Solution of Sample" to boiling; add 2 or 3 drops of methyl red indicator, and then dilute ammonium hydroxide drop by drop to a yellow end point. Boil from 1 to 2 minutes and filter immediately. Transfer the contents of the dish or beaker to the filter with hot 2% neutral ammonium chloride and wash 5 times with this solution. Dissolve the precipitate in the minimum amount of hot hydrochloric acid (1–10) receiving the washings in the original beaker in which the precipitation was made. Wash the filter thoroughly with hot water and reserve. Precipitate again as before with the aid of macerated filter paper if desired to aid in filtering. Transfer the precipitate quantitatively to a filter with hot neutral 2% ammonium chloride or ammonium nitrate and wash 6 times with either of these solutions.

Place the reserved paper and the precipitate and paper in a previously ignited platinum crucible weighed with cover; dry, and ignite under good oxidizing conditions at approximately 1100°C, finally covered. Cool in a desiccator over a good desiccant, never calcium chloride, and quickly weigh the covered crucible. Repeat the ignition until constant weight of "R_2O_3" is obtained.

(D) CaO

Combine the filtrates from the two R_2O_3 precipitations, make slightly acid with dilute hydrochloric acid and evaporate to a volume of about 150cc. Add a slight excess of dilute ammonium hydroxide and heat to boiling. Add slowly, with constant stirring, 10cc. of a 4% solution of ammonium oxalate and boil 5 minutes. Let stand on steam bath for at least 4 hours or preferably over night.

Transfer the precipitate to a small filter and wash with ten 5cc. portions of cool 1% ammonium oxalate solution. Place in an ignited platinum crucible weighed with cover, dry, and ignite at approximately 1000°C. Cool over a good desiccant, never over calcium chloride, and quickly weigh the covered crucible. Repeat the ignition until constant weight is obtained.

(E) MgO

Make the filtrate from the oxalate precipitation distinctly acid with HCl, and add $\frac{1}{2}$ gram of diammonium phosphate $(NH_4)2HPO_4$; evaporate to 150cc. and cool. Add ammonium hydroxide slowly to a slight excess. Stir vigorously until precipitation begins. After several minutes add ammonium hydroxide (specific gravity 0.90) to make one-ninth by volume. Let stand over night. Filter on a previously ignited and weighed Gooch crucible or on filter paper if

so desired. Wash with 5% by volume ammonium hydroxide 5 times; dry and ignite gently. Finally ignite to constant weight at 1100°C as $Mg_2P_2O_7$.

(F) Ignition Loss

Ignite 5 grams of sample at approximately 1100°C in an ignited and weighed platinum crucible to constant weight. Report the loss in weight of the sample as per cent ignition loss.

29. THE DETERMINATION OF IRON (AS FE_2O_3), TITANIA, AND ZIRCONIA IN GLASS SANDS[1]

(A) Determination of Iron

Weigh a 10-gram sample of the sand into a platinum dish of 150cc. capacity. (It is not necessary to grind the sand). Moisten the sample with water and add 2cc. concentrated H_2SO_4. Mix thoroughly by shaking the dish. HF(C.P. 48%) is now added until a few drops no longer produce any reaction. This reaction is not violent unless the sand is ground.

Fill the dish two-thirds full with HF, place on the sand bath, or hot plate, and evaporate.

The sand becomes flocculent and may completely dissolve. In the latter case, the evaporation is carried to H_2SO_4 fumes, rapidly at first, then carefully to avoid loss by spattering.

In case the solution is not complete carry the evaporation down half way, then refill the dish with HF, and evaporate to dryness.

Ignite the dish containing the residue for a few minutes at approximately 1000°C to drive off all H_2SO_4 and destroy any organic matter that may be present.

Cool the dish containing the residue and add 25cc. HCl (1:1), cover with a watch glass, heat to boiling, and filter into a 500-cc. beaker. Wash the filter paper four times with hot H_2O.

Return the paper to the dish and ignite. Make a quick fusion with Na_2CO_3 (2 grams, 5 minutes). Dissolve the melt in dilute HCl (1:1) and add to the main solution, disregarding any silica that may have been carried over. Neutralize the main solution with ammonium hydroxide and then add enough dilute sulphuric acid to have a slight acidity to litmus paper. Thoroughly saturate the solution with hydrogen sulphide, digest for one-half hour and filter. Wash the filter thoroughly with hot water. Boil off the excess hydrogen sulphide from the filtrate and add a few drops of concentrated nitric acid. Heat the solution to boiling

[1] Glass Division, Standards Committee, AMERICAN CERAMIC SOCIETY.

and add a slight excess of ammonium hydroxide. Boil from 1 to 2 minutes and filter quantitatively. Redissolve the precipitate with hot dilute (1:4) hydrochloric acid and again precipitate with ammonia. Filter, wash 4 times with hot water, and dissolve the precipitate from the paper with hot hydrochloric acid (1:1) receiving the solution in a 500-cc. Erlenmeyer flask. Wash the filter thoroughly with hot water. Add 1:1 HCl (and concentrated HCl equal to the volume of wash water used) to bring the volume up to 200cc. Cover with a watch glass and heat to boiling. Cool the neck of the flask with a stream of cold water. Reduce the iron with stannous chloride (minimum number of drops). Adjust the titration head, insert the burette tip, and titrate with standard $K_2Cr_2O_7$, while recording the potential by means of a Roberts Electrometric Titration Apparatus. From the potential-titration curve ascertain the number of cubic centimeters of $K_2Cr_2O_7$ solution required by the iron chloride in the solution.

Calculate the percentage of total iron as Fe_2O_3. Report as Fe_2O_3. A blank is run on the reagents used and the blank subtracted from the titration.

NOTE: Where the very highest accuracy for the iron determination is not desired, the sulphuric acid treatment and removal of the platinum metals with hydrogen sulphide may be omitted.

(B) Determination of Titania

Fuse the ignited and weighed "R_2O_3" residue with 1 to 2g. of potassium pyrosulphate and take up the melt in 30cc. of dilute sulphuric acid (1:9).

Transfer the solution to a Nessler comparison tube, rinse with a very little of the acid, add 3cc. of fresh hydrogen peroxide, and dilute with the acid to 50cc. In another tube dissolve an equal amount of pyrosulphate in the dilute acid, add 3cc. of the peroxide, and dilute with acid to the same volume. To the comparison tube add a standard solution of titanium sulphate, $Ti(SO_4)_2$, until the colors in the two tubes are exactly the same when the solutions are thoroughly mixed. The amount of titanium oxide added, divided by the total volume of the solution represents the amount of titania per cubic centimeter of the unknown solution. This value multiplied by 50 represents the amount of titanium oxide in the sample taken for analysis. It is not likely that a glass sand will contain so much titanium that the color in 50cc. of a solution obtained from a 1-g. sample will be too strong for colorimetric comparison.

The standard solution of titanium sulphate can be prepared from titanium oxide of known purity or from potassium titanium fluoride,

K_2TiF_6. The former can be fused with potassium pyrosulphate, the melt dissolved in dilute sulphuric acid and the solution diluted to the desired volume with the same acid. If the fluoride is used, purify the salt by crystallization from hot water in platinum and dry the crystals. Treat the calculated weight of the dried crystals with sulphuric acid in platinum, evaporate to fumes, cool the solution, and wash the walls of the vessel with water. Repeat the evaporation and washing twice to make sure that all fluorine is expelled. Cool the solution, prepare a dilute sulphuric acid (1:9) solution of the desired volume, and determine its titer by precipitation with ammonia and final ignition to TiO_2.

(C) Determination of Zirconia

In order to determine zirconia add 5.0g. of diammonium phosphate, $(NH_4)_2HPO_4$, to the solution that was used for the determination of titania and which should still contain hydrogen peroxide, and approximately 10% of sulphuric acid by volume. Cover and allow to stand over night at a temperature of 40 to 50°C. Hydrogen peroxide must be present in excess at all times. If a precipitate appears, filter the solution and wash the paper and precipitate with a cold 5-% solution of ammonium nitrate. Dry the paper and precipitate in a weighed platinum crucible; cautiously burn off the carbon, and finally heat at approximately 1000°C. Cool and weigh as ZrP_2O_7 which contains 46.3% of zirconium oxide.

(D) Al_2O_3

Alumina is determined by subtracting from the total R_2O_3 the percentages found for Fe_2O_3, TiO_2, and ZrO_2.

(E) SiO_2

Silica is determined by difference by subtracting the percentages of R_2O_3, CaO, MgO, and ignition loss from 100.

(F) Blank

Run a blank determination on the reagents, using exactly the same amounts of chemicals as in the original analysis. Subtract any impurities from the amounts found in the analysis of the sand.

(1) Electrometric Determination of Iron[1]

To determine the oxidation-reduction potential of a given solution, it is sufficient to determine the potential difference between a platinum

[1] J. C. Hostetter and H. S. Roberts, *Jour. Amer. Chem. Soc.*, **41**, 1337 (1919); H. S. Roberts; *ibid*, **41**, 1358 (1919).

electrode and a standard electrode, the standard electrode usually being a calomel electrode connected to the solution by means of a salt bridge.

In the titration of a solution in oxidimetry the shift in potential resulting from a given addition of the titrating reagent depends not on the actual amount of the reagent added, but on the percentage alteration in the quantity of the material governing the potential of the solution. As the end point is approached, therefore, small additions of the titrating solution will produce increasingly great changes in potential, and after the end point is passed decreasingly great changes in potential. The maximum change occurs at the end point.

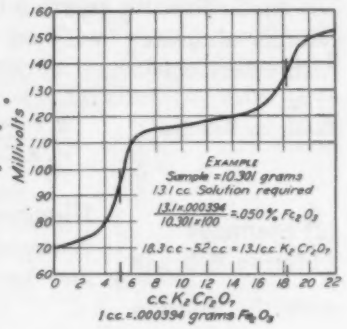

FIG. 1.

If the potentials be plotted against volume of the titrating solution we have a curve with a point of inflection at the end point of the reaction.

In the determination of iron by titration with potassium dichromate in hydrochloric acid subsequent to reduction with an excess of stannous chloride in hydrochloric acid, we have the following reactions:

$$3\ SnCl_2 + K_2Cr_2O_7 + 14\ HCl \rightarrow 2\ CrCl_3 + 3\ SnCl_4 + 2\ KCl + 7\ H_2O$$
$$6\ FeCl_2 + K_2Cr_2O_7 + 14\ HCl \rightarrow 2\ CrCl_3 + 6\ FeCl_3 + 2\ KCl + 7\ H_2O.$$

The first reaction is completed before the second begins owing to the lower potential of stannous chloride. Hence we have two end points, or two points of inflection in the curve of potential against volume of potassium bichromate solution.

The second reaction is the one we desire to measure. It is the one taking place between the two end points. Hence our titration is the volume of solution added between the two end points.

The oxygen of the air will also effect the oxidation of both the stannous chloride and ferrous chloride. By using a narrow-mouthed flask this oxidation is so slow that by rapid work no appreciable error results. For extreme accuracy a flow of carbon dioxide should be maintained for at least five minutes before the titration and continued during the titration.

(G) Apparatus

(1) Standard Solution For the electrometric titration of iron in glass or glass-making materials the most convenient strength of potassium dichromate is 0.005 *N*. Of this solution 1.00cc.

=0.000399g. iron oxide. To make up this solution dissolve 4.9g. of C.P. potassium dichromate in 100cc. hot distilled water and dilute to 20 liters. Shake well.

Standardize this solution by titrating electrometrically in the usual manner accurately weighed samples of C.P. iron wire newly polished with emery cloth.

Factor on Solution

$$\frac{\text{g. Fe wire} \times 79.84}{\text{cc. } K_2Cr_2O_7 \times 55.84} = \text{g. } Fe_2O \text{ cc.}$$

(2) Stannous Chloride Solution

Dissolve 113g. stannous chloride in 200cc. concentrated hydrochloric acid. Dilute to one liter and keep a few pieces of tin metal in contact with the solution.

(3) Brine Solution for Salt Bridge

Make a saturated solution of sodium chloride and arrange the customary glass siphon with about twelve inches of rubber tubing to connect with the half cell. A spring pinch clamp conserves the brine satisfactorily. Two liters of the brine should last several months.

In the Roberts Titration Potentiometer we have a sliding contact, *F*, making contact with the resistance coil, *BD*, divided into 200 equal divisions. In parallel therewith are two fixed resistances, *AE* and *EC*, in series with each other and having resistances in the proportion 140 to 60. *E* is connected to *F* through a galvanometer and the titration cell. Since *AB* and *CD* have negligible resistance *A* is at the same potential as *B* and *C* as *D*. That is, *AC* equals *BD* in voltage drop. The potential drop of *BF* to *FD* is proportional to the divisions. The potential drop of *AE* is to that of *EC* as 140 is to 60.

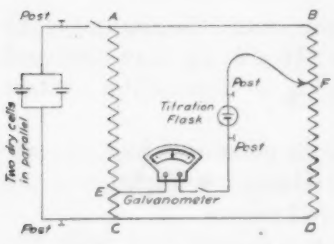

FIG. 2.— Wiring diagram of Roberts titration potentiometer.

When contact is made across *EF* a current will flow and deflect the galvanometer unless the position of *F* is such that its potential, less that of the titration cell, is equal to that of *E*. Accordingly, if we adjust *F* so that no current is indicated by the galvanometer, the reading *F*–60 is proportional to the potential of the titration cell. For the purpose to which the Roberts is put, direct readings of *F* (an arbitrary measure of the potential) are sufficient, for the addition of 60 to the potentials merely shifts the whole volume-potential curve upward without altering its shape.

The calomel electrode is assembled by placing in the bottom of the arm about one-fourth inch of freshly cleaned mercury. (Cleaned by filtering, or washing with nitric acid). One-quarter inch of dry calomel is then placed on top of the mercury and water or brine added to moisten the calomel. Stirring will help wet the calomel. Care must be taken, however, not to mix with the mercury. Connect then with the brine and be sure to sweep out all bubbles and allow the brine time enough to displace the water in the calomel. The wires leading from the platinum connections on the half cell to the potentiometer are annunciator wire. The platinum electrode should occasionally be ignited in a flame. It should be kept standing in hydrochloric acid.

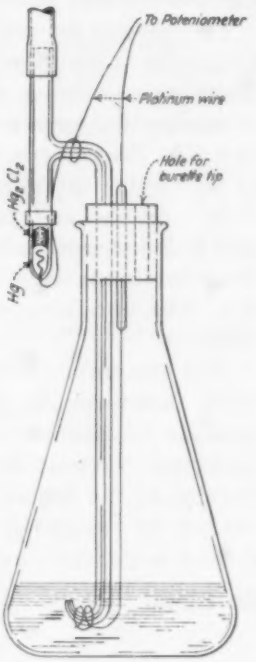

FIG. 3.

(H) Procedure

To determine electrometrically the iron in any glass or glass-making material it is first necessary to get the iron into solution in 1:1 hydrochloric acid. For the methods of effecting solution see the particular material under consideration.

Having obtained solution of the iron in 1:1 hydrochloric acid (150cc.) in a 500-cc. Erlenmeyer flask, bring the acid solution to boiling, let cool so that the flask can be shaken by hand, add the minimum number of drops of stannous chloride in hydrochloric acid (usual qualitative reagent) to decolorize the ferric iron. Wash the titration head with distilled water and flow out a few drops of brine from the salt bridge to prevent contamination from the last analysis. Insert the titration head in the Erlenmeyer and insert the tip of the burette through the hole provided in the titration head.

Close the switches on the Roberts potentiometer and balance the potentiometer. (Turn the wheel so that the galvanometer reads zero). Shake the solution well and again balance. If the reading of the potentiometer is less than 70, add a few cubic centimeters of potassium dichromate solution, shake well, and balance the potentiometer. If the potentiometer reading is over 70, oxidation of the stannous chloride by the air is a sufficient factor to cause a continuing shift in the potential. This oxidation will destroy all the stannous chloride in a few

minutes. The air will also oxidize ferrous chloride, so that it is necessary to start the titration just as soon as the end point of the stannous chloride is reached. This point with new batteries is 85–90 and with old batteries 95–100.

It is determined as half way between the last stable potential while stannous chloride is in the solution and the first stable potential after the stannous chloride is all destroyed. Another means of identifying this point is that at this point the solution begins to turn faintly yellow.

The burette reading at this point should be noted for it is the beginning point of titration. Add quickly a considerable amount of potassium dichromate solution shake and balance, govern the next addition of potassium dichromate by the potential obtained on each previous addition. As the end point is approached, decrease the additions to 1/100 of the total titration and record the titration and corresponding potentials. As the end point is approached, after each addition, shake and balance repeatedly until a constant balance is established. Continue additions beyond the end point until each addition produces less than one-third of the greatest change produced by any equal addition.

Plot the curve of the potential against burette readings and determine therefrom the point of inflection. After a little practice it is possible to estimate the point of inflection by an inspection of the potentials without drawing the curve. Subtract the reading of the burette at the beginning point of the iron titration from the burette reading at the end point (point of inflection last obtained). The difference is the measure of the iron oxide present in the sample.

Calculation

$$\frac{\text{cc.} \times \text{factor} \times 100\%}{\text{gram sample}} = \text{Fe}_2\text{O}_3 \text{ in sample}$$

NOTE: If desired the titration may be repeated merely by reducing and titrating as before.

NOTE: It occasionally happens that a bubble gets in the capillary salt bridge and breaks contact, so that turning the potentiometer wheel makes no change in the galvanometer. The remedy is to flow enough of the brine to sweep the bubble out of the capillary.

Another cause of breaking contact is corrosion of the copper wires at the point of contact with the platinum wires. The junctions should be disconnected and the copper wires scraped. On reconnecting no trouble should be experienced.

Sand is likely to accumulate in the tip of the salt bridge. It does no harm as long as it is possible for the brine to flow slightly.

NOTE: Be sure the galvanometer needle comes to rest at zero when no current is flowing.

NOTE: In the procedure recommended by Hostetter and Roberts, the solution is blanketed throughout the titration by some nonoxidizing gas, as carbon dioxide. The carbon dioxide is introduced through the titration head by means of a T-tube, one leg

of which affords a means of exit for the platinum electrode. The exit gases flow out around the burette tip.

This procedure is more strictly accurate than the one described above. It gives a smooth curve at the beginning point of the titration and eliminates the necessity for haste at that point. However, if the titration without the carbon dioxide blanket is conducted rapidly the same result is obtained as with the carbon dioxide. Twice as many titrations may be made in an hour without carbon dioxide and one is saved the nuisance of the carbon dioxide generator.

NOTE: The end point in the determination of iron in sand is more sharp than in the determination of iron in lime or feldspar. More care is therefore necessary in following the potential changes in these cases than with sand.

NOTE: Nitrates interfere with the titration owing to their slow and continuing tendency to oxidize the stannous chloride and ferrous chloride. They should be destroyed before starting the titration. Removal is effected by precipitating the iron as hydroxide and filtering off the liquid, then redissolving the iron. Filtrates may be destroyed by long continued boiling with an excess of stannous chloride.

NOTE: The method is independent of the presence of titanium for the reduction potential of titanous chloride is similar to that of stannous chloride, so that it is all oxidized before the ferrous chloride begins to be affected.

The method is independent of the presence of chromium, for it would be converted to chromic chloride by the stannous chloride and chromic chloride is one of the products of the reaction.

NOTE: Copper is included in the results, as its curve is very closely like that of iron.

Vanadium is included in the results, but is not apt to be met with.

V. STANDARD SPECIFICATIONS FOR MATERIALS

30. CERAMIC WHITING[1]

(A) General

(1) Definition Ceramic whiting is a finely ground white powder composed of nearly pure calcium carbonate or calcium carbonate and magnesium carbonate obtained from pulverizing and sizing chalk, marble, or limestone, or as a chemically precipitated product.

(2) Use in Ceramic Products Whiting is used to furnish the calcium oxide component of glazes, enamels, and fluxed ceramic bodies. It is an active fluxing agent, rarely used in large quantities in body mixtures. It may be used either as a raw ingredient in glazes, or fritted or smelted with other glaze materials before application.

(3) Packing Whiting is packed and shipped in barrels which do not hold more than 325 pounds or bags which do not hold more than 125 pounds. The package should be labeled stating whether the content is natural rock whiting or chemically precipitated whiting.

(B) Requirements

(1) Quality Whiting shall be uniform in quality (from shipment to shipment), both as to fineness of grain and composition. The calcium, magnesium, or total carbonates shall not vary more than $\pm 1\%$ and the silica not more than $\pm \frac{1}{2}$ of 1% of a figure set by contract within the limits of the composition shown in Class 1 or Class 2. It should be manufactured from the purest rock available and should be free from particles of pyrites, iron-bearing silicates, metallic iron, and gypsum.

(2) Composition Whitings shall be divided into two classes, No. 1 being practically a pure calcium carbonate and No. 2 containing calcium carbonate with a considerable percentage of magnesium carbonate within the limits of the composition given. This does not indicate that one class is inferior in quality to the other, but indicates that numerous users prefer the magnesium whiting to the pure calcium whiting.

CLASS 1

Material	Total carbonates	$CaCO_3$	$MgCO_3$	Fe_2O_3	SiO_2	SO_3
Maximum	—	—	1%	0.25%	2.0%	0.1%
Minimum	97%	96%	—	—	—	—

[1] Revised April 7, 1923; adopted, 1924.

CLASS 2

Material	Total carbonates	$CaCO_3$	$MgCO_3$	Fe_2O_3	SiO_2	SO_3
Maximum.....	—	—	8%	0.25%	2.0%	0.1%
Minimum.....	97%	89%	—	—	—	—

(3) Fineness Screening samples by washing for ten minutes with a stream of water practically without pressure shall not leave a residue of more than 1% on a No. 140 screen (or more than 2% on a No. 200 screen), and at least 98% of the material shall pass a No. 200 screen. It shall also be so fine that a separation made by a Pearson[1] air separator will show at least 85% of the material finer than .02 mm. and at least 48% finer than .01 mm.

As an alternative to the Pearson air separator method the following (not so desirable) may be used: 2g. of the material shall be shaken for ten minutes in a 250-cc. cylindrical graduate with 250cc. of distilled water. On allowing to settle it shall require not less than 20 minutes for visible settling to cease when the cylinder is viewed in reflected light, using clear north sky light for illumination.

(4) Marking Each shipment of material shall be legibly marked with the names of consignor and consignee and with some means of identifying the particular contract on which the shipment is made.

(5) Retesting Notice of the rejection of a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within five days of receipt of said notice.

(C) Sampling and Testing

(1) Sampling Twenty-five per cent of the number of packages shall be selected for sampling. A core representing the contents of each of these packages shall be taken with a sampling tube. The total material so collected shall weigh not less than 5 lbs. This shall be thoroughly mixed and quartered to provide a $^1/_2$-lb. sample for the laboratory.

(2) Testing The following directions are a brief summary of the analytical methods which are recommended.[2] Blast

[1] The Pearson air separator developed at the Bureau of Standards by J. C. Pearson and F. A. Hitchcock gives excellent separations of fine dry powders and is the only machine which can be used for this purpose for particles as small as .01 mm. Its use is therefore recommended for manufacturers and users of fine powder such as whiting, flint, feldspar, paint pigments, etc.

[2] For more complete information on this subject reference should be made to "The Analysis of Silicate and Carbonate Rocks," by W. F. Hillebrand, U. S. Geol. Surv., *Bull.*, No. 700.

0.5g. of the sample for 15 minutes in a platinum crucible. Cool and transfer to an evaporating dish. Mix to a slurry with distilled water. Add 5 to 10cc. concentrated HCl. Heat gently until solution is complete, breaking up lumps if necessary. Evaporate to dryness on water bath. Add 15cc. concentrated HCl and dilute with an equal volume of distilled water. Digest on water bath for 10 minutes. Filter and wash with hot water. Evaporate the filtrate to dryness. Dissolve in acid and water as before. Filter and wash with hot water. Ignite the two precipitates together and weigh as silica and insoluble matter.

Dilute the above filtrate to 250cc. Make alkaline with NH_4OH. Boil until odor of NH_3 is barely noticeable. Filter and wash slightly with hot water. Dissolve the precipitate with hot dilute HCl and repeat the precipitation as before. Filter and wash thoroughly with hot water. Ignite and weigh as oxides of iron, aluminum, and phosphorus.

To the filtrates from the above add a few drops of NH_4OH and bring to a boil. Add 25cc. of a saturated solution of $(NH_4)_2C_2O_4$. Continue boiling until the precipitate becomes granular. Let stand one hour. Filter and wash with hot water. Ignite the precipitate, dissolve in dilute HCl, and dilute to 100cc. Add excess of NH_4OH and boil. Filter out any insoluble matter, ignite and weigh; add its weight to the oxides of iron and aluminum found previously. To this filtrate add $(NH_4)_2C_2O_4$, proceeding as before. Filter, and wash with boiling water. Ignite, and blast to constant weight as calcium oxide.

Acidify the filtrates from the above with HCl. Add 10cc. of a saturated solution of $NaNH_4HPO_4$ and evaporate to 150cc.; cool; add NH_4OH drop by drop with constant stirring until the precipitate starts to form. Then add moderate excess of NH_4OH. Stir for several minutes. Let stand over night. Filter and dissolve the precipitate in hot dilute HCl.

Dilute to 100cc., add 1cc. of saturated solution of $NaNH_4HPO_4$ and precipitate as before. Filter and wash with dilute NH_4OH (25% NH_3 containing a few drops of HNO_3); ignite and weigh as Mg_2P_2O; multiply this weight by 0.3621 to find the weight of MgO.

Place 0.5g. of the sample in a small Erlenmeyer flask and cover with hot distilled water. Connect this flask into a carbon-dioxide train, set up as follows: Next to the flask is a reflux condenser, to which is connected a calcium-chloride drying tube followed by a tube containing anhydrous $CuSO_4$, then another tube of $CaCl_2$, then by two tubes filled with soda lime, and finally by another tube of $CaCl_2$. The entire train must be so arranged that a stream of CO_2 free air can be kept passing through it. Start this stream of air. Weigh the tubes containing soda lime and replace them in the train. Add to the sample in the flask about 25cc. of 1:1 HCl, being careful that no gas is lost and

that the effervescence is not too violent during the operation. When the effervescence diminishes, heat the flask, bringing the liquid gradually to boiling. Boil for 10 minutes. Remove the flame and allow the flask to cool, while the stream of air is still flowing, for 15 minutes. Disconnect and weigh the soda lime tubes. Their increase in weight is recorded as carbon dioxide.

To five grams of the sample in a covered vessel, add 25cc. of water, and then cautiously 10cc. of concentrated hydrochloric acid. Break up any lumps with the flattened end of a glass rod and boil for 2 or 3 minutes. Reduce the hot solution with a few drops of stannous chloride solution; cool; dilute to 100cc., add 10cc. of mercuric chloride solution, and titrate with standard potassium dichromate solution ($N/20$), using potassium ferricyanide as outside indicator. Calculate the results to Fe_2O_3. A blank determination is desirable for comparison.

The permanganate method for determination of total iron, as given by Blair in "The Chemical Analysis of Iron," may also be used.

Fuse 2.5g. of the sample with about 10g. of sodium carbonate, and dissolve the melt in 10% hydrochloric acid. (Any insoluble residue should be filtered off and tested by flame test for barium. If barium is absent, the residue may be rejected; if present, the residue should be again fused with an excess of sodium carbonate, and the water extract tested for SO_3.) Dilute the clear solution to 250cc., heat to boiling, and add slowly 10cc. of hot 10% solution of barium chloride. Formation of a white precipitate indicates the presence of sulphur. A blank test should be made to insure the purity of reagents used.

For extremely accurate work any insoluble matter may be filtered off at this point, ignited, fused with sodium carbonate, and the melt dissolved in 10% hydrochloric acid and added to the filtrate.

31. LIMESTONE, QUICKLIME, AND HYDRATED LIME[1]

(A) General

(For Use in the Manufacture of Glass)

(1) Use of Lime Most common glasses are fused mixtures of alkali (usually soda), alkaline earth (usually lime), and silica. Freedom from color is important in determining the quality of glass, which, in turn, depends upon the absence of coloring oxides (usually iron) from the raw material.

Limestone, quicklime, or hydrated lime may be used for making glass. The decision as to which to use is generally based on availability, cost, and present practice.

[1] Issued by Department of Commerce, U. S. Bur. Stand., *Circ.*, No. 118, Dec. 8, 1921. Adopted 1924.

(2) Definition of Limestone, Quicklime, and Hydrated Lime Limestone consists essentially of calcium carbonate, or of calcium and magnesium carbonates where the amount of the latter does not exceed 45.5%. Quicklime is the product resulting from the calcination of limestone and consists essentially of calcium oxide, or of calcium and magnesium oxides. It will slake when water is added to it, and this slaking is accompanied by an evolution of heat and an increase in volume. Hydrated lime is a dry powder which is made by treating quicklime with enough water to satisfy its chemical affinity under the conditions of manufacture. It consists essentially of calcium hydroxide, or of a mixture of calcium hydroxide and magnesium oxide or hydroxide.

(3) Packing Limestone is shipped in bulk in carload lots, or in cloth or paper bags. Quicklime is shipped either in bulk in carload lots or barrels holding 180 pounds net or 280 pounds net each. Hydrated lime is shipped in paper bags holding 50 pounds net each.

(B) Requirements

(1) Quality Except for the constituents enumerated below, the composition of a limestone, lime, or hydrated lime may vary within wide limits and still be satisfactory to the glass manufacturer. Either high calcium or high magnesium material may be used. It is essential, however, that the composition be reasonably uniform from day to day. Otherwise the difficulty of controlling the process of manufacture would become too great.

(2) Composition Quicklime shall not contain more than 3% CO_2 as shipped. Hydrated lime shall not contain more than 5% CO_2 as shipped, and shall contain sufficient water to meet the chemical requirements of the calcium oxide.

Limestones, quicklimes, and hydrated limes may be divided into three classes, depending upon the character of glass for which they are suitable. To meet these specifications, the constituents listed below shall not exceed the maximum percentages or fall below the minimum percentages given in the following table:

TABLE I

COMPOSITION OF THE NONVOLATILE PORTION OF LIMESTONE, QUICKLIME, OR HYDRATED LIME

Ingredients	Class 1		Class 2		Class 3	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
$CaO+MgO$	—	96	—	91	—	83
Fe_2O_3	0.2	—	0.4	—	0.8	—
SO_3+P_2O						
(*a*) In limestone	1.0	—	1.0	—	1.0	—
(*b*) In quicklime or hydrated lime	3.0	—	3.0	—	3.0	—
SiO_2	4.0	—	9.0	—	17.0	—
Al_2O_3	3.0	—	5.0	—	5.0	—

The sum of the calcium and magnesium oxide is specified in the above table. In order to prevent undue variation in the relative proportions of these two ingredients the per cent calcium oxide shall be established by contract, and it is specified that the per cent calcium oxide shall not vary more than 2% either way from the contract figure.

An approximate figure for the content of alumina should also be included in the contract. This figure must come within the limits set in the above table, and it is specified that the amount of alumina in the material delivered shall not vary more than 1% either way from the contract figure.

(3) Fineness Unless otherwise specified, limestone, quicklime, and hydrated lime shall be crushed so that all will pass a No. 16 sieve.

NOTE: A No. 16 sieve has an opening of 1.19 mm. and a wire diameter of 0.54 mm. with a permissible tolerance of 2% in the opening and 10% in the wire diameter.

(4) Marking Each carload of material, or fraction thereof, shall be legibly marked with the names of the consignor and consignee, and with some means of identifying the particular contract on which the shipment is made.

This information is in addition to that required by the Federal Lime-Barrel Law.

(5) Retesting Notice of the rejection of a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of the notice of rejection. The consignee shall provide all reasonable facilities to permit the consignor to resample the material. This retest shall be at the expense of the consignor.

(C) Sampling and Testing

(1) Sampling The purchaser will bear all expense of sampling and testing. When limestone or quicklime is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers, which are most subject to changes. The sample shall consist of 1 shovelful for each 3 tons of material, but not less than 10 shovelfuls, taken from different parts of the shipment. The total sample taken shall weigh at least 100 pounds, shall be mixed thoroughly, and "quartered" to provide a 15-pound sample for the laboratory. In case a shipment consists of more than one car, a separate sample shall be taken from each car.

When quicklime is shipped in barrels, at least 3% of the number of barrels shall be sampled. They shall be taken from various parts of

the shipment, dumped, mixed, and sampled as specified in the above paragraph.

In the case of hydrated lime the sample shall be a fair average of the shipment. Three per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. The material so obtained shall be thoroughly mixed and quartered to provide a 2-pound sample for the laboratory.

When sampling quicklime or hydrated lime, it is essential that the operation be conducted as expeditiously as possible, in order to avoid undue exposure of the material to the air. The sample to be sent to the laboratory shall immediately be placed in an air-tight container in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

The sample may be taken either at the point of shipment or at the point of destination, as agreed upon by the contracting parties. If it is desired to enforce the requirements as to carbon dioxide, the sample must be taken at the point of shipment.

(2) Testing The following directions are a brief summary of the analytical methods which are recommended.[1] Blast 0.5g. of the sample for 15 minutes in a platinum crucible. Cool and transfer to an evaporating dish. Mix to a slurry with distilled water. Add 5 to 10cc. concentrated HCl. Heat gently until solution is complete, breaking up lumps if necessary. Evaporate to dryness on water bath. Add 5 to 10cc. concentrated HCl and dilute with an equal volume of distilled water. Digest on water bath for 10 minutes. Filter and wash with hot water. Evaporate the filtrate to dryness. Dissolve in acid and water as before. Filter and wash with hot water. Ignite the two precipitates together and weigh as silica and insoluble matter.

Dilute the above filtrate to 250cc.; add HCl if necessary to insure a total volume of 10 to 15cc.; make alkaline with NH_4OH; boil until odor of NH_3 is barely noticeable. Filter, and wash slightly with hot water. Dissolve the precipitate with hot dilute HCl and repeat the precipitation as before. Filter and wash thoroughly with hot water. Ignite and weigh as oxides of iron, aluminum, and phosphorus.

To the filtrates from the above add a few drops of NH_4OH and bring to a boil. Add 25cc. of a saturated solution of $(NH_4)_2C_2O_4$. Continue boiling until the precipitate becomes granular. Let stand until precipitate settles clear. Filter and wash with boiling water. Ignite the precipitate, dissolve in dilute HCl, and dilute to 100cc. Add excess of NH_4OH, and boil. Filter out any insoluble matter; ignite and weigh; add its weight to the oxides of iron and aluminum found previously.

[1] See W. F. Hillebrand, *loc. cit.*

To this filtrate add $(NH_4)_2C_2O_4$, proceeding as before. Filter and wash with boiling water. Ignite and blast to constant weight as calcium oxide.

Acidify the filtrates from the above with HCl. Evaporate to 150cc. Add 10cc. of a saturated solution of $NaNH_4HPO_4$ and boil; cool; add NH_4OH drop by drop, with constant stirring, until the precipitate starts to form. Then add moderate excess of NH_4OH. Stir for several minutes. Let stand over night. Filter and dissolve the precipitate in hot dilute HCl. Dilute to 100cc., add 1cc. of saturated solution of $NaNH_4HPO_4$, and precipitate as before. Filter, and wash with an alkaline solution made by diluting NH_4OH until it contains about 2.5% NH_3 and then add a few drops of HNO_3; ignite and weigh as $Mg_2P_2O_7$; multiply this weight by 0.3621 to find the weight of MgO.

Place 5g. of the sample of quicklime or hydrated lime, or 0.5g. of limestone, in a small Erlenmeyer flask and cover with hot distilled water. Connect this flask into a carbon-dioxide train, set up as follows: Next to the flask is a reflux condenser, to which is connected a calcium-chloride drying tube, followed by a tube containing anhydrous $CuSO_4$, then another tube of $CaCl_2$, then by two tubes filled with soda lime, and finally by another tube of $CaCl_2$. The entire train must be so arranged that a stream of CO_2 free air can be kept passing through it. Start this stream of air. Weigh the tubes containing soda lime and replace them in the train. Add to the sample in the flask about 25cc. of 1:1HCl, being careful that no gas is lost and that the effervescence is not too violent during the operation. When the effervescence diminishes, heat the flask, bringing the liquid gradually to boiling. Boil for 10 minutes. Remove the flame and allow the flask to cool for 15 minutes, while the stream of air is still flowing. Disconnect and weigh the soda-lime tubes. Their increase in weight is recorded as carbon dioxide.

Dissolve 5g. of the sample in HCl and evaporate to dryness. Dissolve the residue in HCl; filter and wash with hot water. Fuse the residue with Na_2CO_3. Treat the filtrate with NaOH in boiling solution; filter and wash with hot water. Dissolve both this precipitate and the fused residue in dilute H_2SO_4. Reduce with Zn and titrate with $N/20$ $KMnO_4$. Calculate the result to per cent Fe_2O_3.

Dissolve 2g. of the sample in 10cc. water and 15cc. 1:1 HCl. Filter out insoluble matter. Dilute filtrate to 250cc. Heat to boiling and add 10cc. of a boiling 10% solution of $BaCl_2$, drop by drop, with constant stirring. Let stand over night; filter; wash with hot water; ignite and weigh as $BaSO_4$. Calculate to per cent SO_3.

Dissolve 10g. of the sample in 80cc. of 1:1 HNO_3; filter; wash; fuse the residue Na_2CO_3; dissolve the melt in HNO_3 and add this solution to the filtrate. Boil the filtrate with 10cc. of 1.5% $KMnO_4$ solution until

MnO_2 is precipitated. Add enough H_2SO_3 to dissolve the MnO_2. Neutralize with NH_4OH. Add 1cc. of concentrated HNO_3 for every 100cc. of solution. Bring to 40°C and precipitate with ammonium molybdate. Shake for 10 minutes and let stand at 40°C for 12 hours. Filter and wash with 1% KNO_3. Dissolve the precipitate in a known volume of $N/10$ NaOH and CO_2 free water. Titrate the excess NaOH, using phenolphthalein as indicator. Calculate the per cent P_2O_5, using the proportion, P:NaOH : : 1:23.

32. FIRE CLAY[1]

(A) Classes

Fire clay shall be of the following classes: (F) fine; (C) commercial.

(B) Material Covered

This specification covers a heat-resistant material composed entirely or principally of fire clay and which is used in laying up fireclay refractories. It shall be sufficiently free from grit and of such quality and plasticity that it will spread satisfactorily with a trowel when tempered with water.

(C) Detail Requirements

(1) The material as furnished shall be air dry and ground to the following fineness: (*a*) Not more than 4% shall be retained on a U. S. Standard Sieve, No. 20.

(*b*) The material shall show satisfactory bonding power.

(*c*) The pyrometric cone equivalent shall be not more than three cones (approximately 60°C or 108°F) lower than that of the fireclay brick or shape with which it is to be used.

(2) The material as furnished shall be air dry and ground to the following fineness: (*a*) Not more than 10% shall be retained on a U. S. Standard Sieve, No. 20.

(*b*) The material shall show satisfactory bonding power.

(3) The pyrometric cone equivalent shall be not more than three cones (approximately 60°C or 108°F) lower than that of the fireclay brick or shape with which it is to be used.

(D) Method of Inspection and Tests

(1) When shipped in containers a sample shall be taken from one of every 100 containers or less. (*a*) The sample shall be taken by dumping the container and quartering the material to provide a 5-pound sample for the laboratory.

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[1] U. S. Govt. Master Specifications, No. 334*a* (revised); adopted 1927.

(*b*) When shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom and shall not contain a disproportionate share of the top and bottom layers. The sample shall consist of 1 shovelful for each 3 tons of material but not less than 10 shovelfuls taken from different parts of the shipment. The total sample taken shall weigh at least 100 pounds and shall be mixed thoroughly and "quartered" to provide a 5-pound sample for the laboratory. In case a shipment consists of more than one car, a sample shall be taken from each car.

(2) One hundred grams of the sample as received shall be placed on a No. 20 sieve and shall be washed by means of a stream of water from a faucet. The washing shall be continued until the water coming through the sieve is clear, but in no case should the washing be continued for more than 30 minutes. The residue on the sieve shall be dried to constant weight at a temperature between 110°C and 150°C. The sieve carrying the dried residue shall then be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the upstroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05g. passes through in one minute of continuous sieving. (*a*) The fineness shall be determined from the weight of the original sample.

A piece of rubber tubing attached to a water faucet is to be used for the washing. The velocity of the water may be increased by pinching the tubing but should not be sufficient to cause any splashing of the sample over the sides of the sieve.

Mechanical sieving devices may be used, but the material shall not be rejected if it meets the fineness requirements when tested by the hand method described.

(*b*) The material shall be tested for bonding power by mixing one portion with water to a creamy consistency and another portion to a good troweling consistency. These mixtures shall then be used in laying up a pier of three of the fireclay brick, laid flat, with which the clay is to be used in service. The faces of the brick to be bonded shall be dipped in the mixture of creamy consistency, a thin layer of the other mixture added, and the brick then firmly rubbed into place. In no case shall the mortar "joint" exceed $\frac{1}{8}$ inch.

When the pier is air dry, it is to be fired uniformly in a suitable furnace to a temperature 300°C or 540°F lower than the minimum allowable softening point of the fireclay brick as defined in the Federal Specifications Board Specification for fireclay brick No. 268. The pier

shall be allowed to cool in the furnace and when cold shall be sufficiently well bonded to remain intact when lifted by grasping the top brick.

(3) The pyrometric cone equivalent is to be determined according to the A.S.T.M. Standard Method of Test for Softening Point C24–20.

(E) Packing and Marking

When delivered in containers, each container shall be plainly marked with the trade name of the material, the contract number, and the name of the contractor.

(F) Notes

Notice of the rejection of a shipment based on this specification must be in the hands of the consignor, unless otherwise specified, within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of said notice.

The cones referred to in this specification are known as the Orton pyrometric cone.

The sieve used shall meet the requirements given in U. S. Bur. Stand., *Letter Circular*, No. 74, or The Tentative Standards of THE AMERICAN CERAMIC SOCIETY. (See Section 6(A) and (B) pp. 345–46.)

VI. SPECIFICATIONS FOR MANUFACTURED PRODUCTS[1]

33. STANDARD SPECIFICATIONS FOR PLASTIC FIRECLAY REFRACTORIES

(A) Material

The material covered by this specification is essentially a mixture of grog, raw clay, and sufficient water to render the mass plastic and of a stiff-mud consistency. The grog is composed principally or entirely of calcined clay, and the raw clay is a plastic grade used to supply the necessary working properties and bond.

(B) Detail Requirements

(1) The material shall contain not more than 65% total silica (SiO_2) calculated on the dry weight.

(2) The pyrometric cone equivalent shall be not less than that of standard pyrometric cone 31 (approximately 1680°C or 3056°F).

(3) The material as delivered shall contain not more than 15% water calculated on the plastic weight.

(4) The total linear dry-and-fired shrinkage shall not exceed 4% of the plastic length.

(C) Method of Inspection

(1) A sample of not less than 50 pounds shall be taken from one container at random for every shipment of one carload or less, and shall be so taken as to be truly representative of the material in the container.

(2) (*a*) The content of total silica shall be determined by analytical methods described under the A.S.T.M. Standard Method, Serial Designation C24–20.

(*b*) The pyrometric cone equivalent shall be determined according to the A.S.T.M. Standard Method of Test for Softening Point, Serial Designation C24–20. (AMERICAN CERAMIC SOCIETY Test, Section 51, p. 452.)

(*c*) The water content shall be determined by drying a specimen of not less than 200g. (approximately 7 ounces) to constant weight at a temperature of not less than 110°C and not more than 150°C. The per cent water shall then be determined in accordance with the following formula:

$$\text{Per cent water} = \frac{W - D}{W} \times 100$$

where

W = the weight of the material as received

D = the weight of the material after having been dried to constant weight

[1] U. S. Govt. Master Specifications, No. 335*a* (revised).

(*d*) The total linear dry and fired shrinkage shall be conducted on brick which have been prepared of the material (as delivered) by hand ramming with a wooden mallet in suitable wooden molds of inside dimensions approximately $2^1/_2$ by $4^1/_2$ by 9 inches. The brick shall be removed immediately from the mold and set on edge on a suitable pallet and marked on the 9- by $4^1/_2$-inch faces with gage marks approximately 8 inches apart. The sample shall then be carefully dried and fired uniformly under no load to 1400°C (2552°F) in not less than five hours and held at this temperature for five hours and allowed to cool in the kiln and without induced draft to room temperature. The distance between gage marks shall be measured to the nearest thirty-second of an inch and the shrinkage calculated in accordance with the following formula:

$$\text{Per cent shrinkage} = \frac{L_w - L_b}{L_w} \times 100$$

where

L_w = length of the specimen in plastic state
L_b = length of specimen after firing at 1400°C

The shrinkage of any one specimen shall be reported as the average of the distance between the two sets of gage marks, and results of any one brand shall be reported as the average of five specimens.

(*e*) The combined results of chemical analyses, softening point, water content, and shrinkage (fired) shall be considered as a suitability test.

(D) Packing and Marking

The material shall be packed in containers so constructed as to insure delivery of the material in satisfactory condition. The size and type of the container shall be as specified by the purchaser.

Each container shall be plainly marked with the trade name of the material, the contract number, and the name of the contractor.

(E) Notes

The consignor shall be notified of the rejection of a shipment based on this specification, unless otherwise specified, within 10 days after receipt of a shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of said notice.

The cones referred to in this specification are known as the Orton pyrometric cones.

The material covered by this specification is particularly adapted to those portions of installations where special fireclay shapes have been or are being used. It is recommended also for the construction of small furnaces such as are used in domestic heating plants, in baking ovens, and in laboratory apparatus.

34. CLAY FIRE BRICK FOR MALLEABLE FURNACES WITH REMOVABLE BUNGS AND FOR ANNEALING OVENS[1]

These specifications are intended to cover only fired products made from fire clay by the usual processes of manufacture and containing not more than 55% alumina or 85% silica. Even within this range of composition, it is not intended to include products other than those regularly sold as clay fire brick.

(A) Purpose and Utility of Specifications

The purpose of these specifications is the selection of clay fire brick that are suitable for service in malleable furnaces under general conditions of operation and of furnace design. Use of this specification, however, shall not relieve the buyer of all responsibility in the selection of the refractories best suited for this particular practice. Of the brands which may meet the requirements some will give better service than others. One brand may give best results in one plant, and a second brand in another plant; or a given brand may give highly satisfactory results in one plant, and fail to do so in another. The reason for this variability in results lies in the almost countless combinations of conditions which exist in plant operation. Some of the factors which directly or indirectly affect the life of the brick are the following:

(1) Factors dependent upon fuel or firing: (*a*) character and kind of fuel, (*b*) character of ash or fluxing ingredients, (*c*) quantity of ash or fluxing ingredients, (*d*) method of firing, (*e*) character of blast and length of flame, (*f*) pressure of blast, and (*g*) direction of flame and impinging of flame upon brick work.

(2) Factors dependent upon furnace design or construction: (*a*) rise and span of arch, (*b*) type of bung frame (*c*) care taken and method followed in laying brick and building bungs, (*d*) tightness with which brick are clamped in bung frames, (*e*) kind of clay used in laying brick, and (*f*) thickness of walls.

(3) Factors dependent upon character of charge: (*a*) kind and amount of scrap used, (*b*) amount of foreign material and rust on scrap, and (*c*) percentage of pig in charge.

(4) Factors dependent upon operating conditions: (*a*) method of charging, (*b*) operating temperature, (*c*) duration of melting period, (*d*) size of heats and number of heats per day, (*e*) care taken and method followed in handling bungs, and (*f*) positions of brick in furnace and practice followed in shifting bungs.

These specifications do not include a requirement for slag resistance, although evidence indicates that the brick, and especially the sidewall

[1] Same as A.S.T.M. Tentative Standard C63–27T (1927).

brick, should be resistant to the corrosive action of slag. In the light of present knowledge, however, none of the slag tests that has been proposed can be regarded as satisfactory for malleable practice.

The bungs and side walls must withstand high operating temperatures. This is insured by the softening point requirement. They must be resistant to rapid temperature changes, hence the spalling test requirement. The spalling requirements for sidewalls have been made less stringent than for bungs, as the spalling conditions are less severe. Sidewall brick must also withstand slag action at the slag line and the brick which are most resistant to slagging do not usually withstand spalling to the highest degree. Practical experience has shown that in bungs and sidewall brick the silica content should not be excessively high. This is cared for by imposing a maximum limit on the percentage of silica. A minimum limit is placed upon the cold breaking strength, merely to insure that the bung brick shall be strong enough to withstand clamping in the bung frames, and to withstand shipping and handling without excessive scuffing. It is recognized that high strength is not necessarily desirable.

Revision of the requirements is to be expected as methods of testing are further perfected, and as the effect of operating conditions upon the life of the brick becomes better understood, clay fire brick which fail to meet the requirements of these specifications, may be regarded as unsatisfactory for general malleable furnace and annealing oven service.

(B) Size Tolerance

Variations (+or−) of 2% from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 inches or over; on dimensions under 4 inches, 3% variation shall be allowed.

(C) Test Requirements on Furnace Bungs

(1) The silica content shall not exceed 65%.

(2) The pyrometric cone equivalent shall not be below cone 31.

(3) Brick as shipped, after subjection to an average of 18 dips in the spalling test (described in Section 63, p. 461), shall not show a loss of more than 20% of their original weights.

(4) The cold modulus of rupture shall not be less than 200 pounds per square inch.

(D) Test Requirements on Side Walls and Bridge Walls

(1) The silica content shall not exceed 65%.

(2) The pyrometric cone equivalent shall not be below cone 31.

(3) Brick as shipped, after subjection to an average of 9 dips in

the spalling test, described later, shall not show a loss of more than 20% of their original weights.

(4) When duplicate samples are heated uniformly to a temperature of 1400°C, maintained at this temperature for 5 hours and cooled, they shall not show a contraction of more than 1.5% of the original length.

(E) Test Requirements on Fire Box Linings and Lower Stack Linings[1]

(1) The pyrometric cone equivalent shall not be under cone 31 for nonsiliceous grade.

(2) The pyrometric cone equivalent shall not be under cone 28 for siliceous grade.

(3) When duplicate samples are heated uniformly to a temperature of 1400°C, maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of more than 1.5% of the original length.

(F) Test Requirements on Upper Stack Lining

(1) The pyrometric cone equivalent shall not be under cone 28.

(2) When duplicate samples are heated uniformly to a temperature of 1350°C, maintained at this temperature for 5 hours and cooled, they shall not show a contraction of more than 1.5% of the original length.

(G) Test Requirements on Annealing Oven Fire Box

For this service the same specifications shall hold as are given for firebox lining of malleable furnaces.

(H) Test Requirements on Annealing Oven Chamber

(1) The pyrometric cone equivalent shall not be under cone 16.

(2) When duplicate samples are heated uniformly to a temperature of 1150°C, maintained at this temperature for 5 hours and cooled, they shall not show a contraction of more than 1.5% of the original length.

(I) Methods of Testing

(1) The determination of silica content shall be made in accordance with the analytical methods described in Standard Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick (Serial Designation: C18), A.S.T.M.

(2) The pyrometric cone equivalent shall be determined in accordance with the Standard Method of Test for Softening Point of Fireclay Brick (Serial Designation: C24), A.S.T.M.

[1] Brick are considered as being of siliceous grade when the silica content is greater than 65% and of a nonsiliceous grade when the silica content is 65% or less.

In the event that the material fails to pass the specified requirements by one cone or less, two additional P.C.E. determinations shall be made as checks on the accuracy of the test and the final results judged on the basis of the three determinations. This procedure is necessary because of variations that have been found to exist in this test even where the standard methods are followed.

(3) The spalling test shall be made on standard 9-inch straight brick, or standard 9- or 13-inch bung brick. This test shall be conducted in accordance with the Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (Serial Designation: C38–27T), A.S.T.M. The test shall be continued until each brick shall have lost 20% by weight or until the total number of immersions necessary to give the required average has been obtained. Individual samples are not to be continued in the test after a loss of 20% has been sustained. The brick shall be dried and weighed before and after testing and the loss computed in per cent of the original dry weight.

The results in the spalling test for any one brand shall be reported as the average loss of 10 specimens selected at random. If desired, the test may be made on only 5 specimens, but when this is done an additional 5 specimens shall be tested in the event that the first 5 do not pass the specification, and the results reported as the average of the entire 10.

(4) The modulus of rupture shall be determined according to the A.S.T.M. standard method for modulus of rupture of building brick, as described in Section 75 (A1–C2), Tentative Methods of Testing Brick (Serial Designation: C67–27T), A.S.T.M. (See pp. 477–80.)

The results in the modulus of rupture test for any one brand shall be reported as the average of 10 specimens selected at random. If desired, the test may be made on only 5 brick, but when this is done an additional 5 specimens shall be tested in the event that the first 5 do not pass the specification, and the results reported as the average of the entire 10.

NOTE: It will be noted that the present Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (C38–27T), A.S.T.M., is the one referred to in these specifications. It is recognized that there are other methods which have much to commend them; the 850°C water dip spalling test developed at the Bureau of Standards; the air-spalling test used by a large contracting company; and possibly others. It seems very probable, however, in the light of past work and that now going on, that the ultimate spalling test may be different from any of these. Everything considered, it seems best to use Method C38 for the present.

35. CLAY FIRE BRICK FOR MARINE BOILER SERVICE[1]

These specifications are intended to cover only fired products made from fire clay by the usual processes of manufacture and containing

[1] A.S.T.M. Tentative Standards, **27** [1], 822–25 (1927). Serial Designation C65–27T. (See page 461, this issue).

not more than 55% alumina or 85% silica. Even within this range of composition it is not intended to include products other than those regularly sold as clay fire brick.

(A) Purpose and Utility of Specifications

The purpose of these specifications is the selection of clay fire brick for marine boiler practice.

Use of the specifications will not relieve the buyer of all responsibility for the selection of the refractories best suited to his particular practice. They may not apply to certain extreme conditions encountered in unusual settings. Of the brands which meet these requirements, some may give highly satisfactory service in one installation and fail to do so in another. Certain brands may give best service in one type of vessel, other brands in another type. The reason for this variability in service lies in the almost countless combinations of conditions which may exist in marine boiler furnace operation. Some of the factors which directly or indirectly affect the life of the refractories are the following:

(1) Factors dependent upon design or construction of the setting: (*a*) furnace volume, (*b*) thickness and height of walls, (*c*) degree of insulation, (*d*) provision for air cooling or water cooling of refractories, (*e*) type of stoker arch, (*f*) height of stoker arch above grates or stoker, (*g*) care taken and method followed in laying brick, and (*h*) character of mortar used in laying brick.

(2) Factors dependent upon fuel and firing: (*a*) hand or mechanical firing, (*b*) type of grate, stoker, or burner, (*c*) character and kind of fuel, (*d*) direction of flame and impingement on brick work, (*e*) character and quantity of ash or fluxing ingredients, and (*f*) fusibility and viscosity of ash.

(3) Factors dependent upon operation: (*a*) vibration and shocks, (*b*) air leaks in furnace walls, (*c*) temperature of operation, (*d*) care and promptness in cleaning boiler tubes, (*e*) continuity of operation, (*f*) character of furnace atmosphere, (*g*) violence of temperature fluctuations, (*h*) rate of operation, (*i*) pressure or draft conditions in furnace, (*j*) care and promptness of making minor repairs, (*k*) method of removing clinker, and (*l*) abrasion of brick work.

The most important causes of failure are softening (fusion), spalling, slag action, and shrinkage. The pyrometric cone equivalent is above the temperature actually attained by the brick work in marine boiler practice. The spalling test specified will select brick of satisfactory resistance to thermal shock for this class of service. In those installations where exceptionally severe spalling seems to occur, the failure of the brick may in many cases be the result of factors which cannot be measured in the spalling test. Such conditions call for study by a competent engineer.

Brick which are subjected to severe slagging conditions in service should not be required to meet a severe spalling test specification. Although slagging is one of the major causes of failure of the refractories, no test for slag resistance is included in these specifications for the reason that in the light of present knowledge none of the methods of making slag tests that have been proposed can be regarded as satisfactory.

Revision of these specifications is to be expected as methods of testing are futher developed and as the effect of operating conditions upon the life of the brick becomes better understood. Clay fire brick, however, which fail to meet the requirements of these specifications may be regarded as unsuitable for marine boiler practice.

(B) Size Tolerance

Variations (±) of 2% from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 in. or over. On dimensions under 4 in., 3% variation shall be allowed.

(C) Test Requirements of Moderate Heat Duty Boiler Settings

(1) The pyrometric cone equivalent shall not be below cone 29 in the case of the nonsiliceous[1] grade and not below cone 27 in the case of the siliceous grade.[1]

(2) When duplicate samples are heated uniformly to a temperature of 1350°C, maintained at that temperature for 5 hours and cooled, they shall not show an average contraction of more than 1.5% of the original length.

(D) Test Requirements on High Heat Duty Boiler Settings

(1) The pyrometric cone equivalent shall not be below 31 in the case of the nonsiliceous grade and not below cone 28 in the case of the siliceous grade.

(2) When duplicate samples are heated uniformly to a temperature of 1400°C, maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of the original length of more than 1.5% in the case of the nonsiliceous grade and 0.75% in the case of the siliceous grade.

(3) When subjected to the spalling test brick shall withstand an average of 5 dips in the case of nonsiliceous grade and 3 dips in the case of the siliceous grade.

(4) Deformation in the standard load test at 1350°C, under a load of 25 lbs. per sq. in., shall not be over 6% in the case of the siliceous grade.

[1] Brick are considered as being siliceous when the silica content is greater than 65% and of nonsiliceous grade when the silica content is 65% or less.

NOTE: The refractoriness of the nonsiliceous grade is assured by the P.C.E., but for this requirement in the case of the siliceous grade, it is necessary to incorporate both the pyrometric cone equivalent and load test.

(E) Test Requirements on Methods of Testing

(1) The determination of silica content shall be made in accordance with the analytical methods described in the Standard Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick (Serial Designation: C18) A.S.T.M.

(2) The pyrometric cone equivalent shall be determined in accordance with the Standard Methods of Test for Softening Point of Fireclay Brick (Serial Designation: C24) A.S.T.M.

In the event that the material fails to pass the specification by one cone or less, two additional softening point determinations shall be made as checks on the accuracy of the test and the final results judged on the basis of the three determinations. This procedure is necessary because of variations that have been found to exist in this test even where the standard methods are followed.

(3) The spalling test shall be conducted in accordance with the Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (Serial Designation C38–27T)[1] A.S.T.M. The test shall be continued until each brick shall have lost 20% or until the total number of immersions necessary to give the required average has been obtained. Individual samples are not to be continued in the test after a loss of 20% has been sustained. The brick shall be dried and weighed before and after treating and the loss computed in per cent of the original dry weight.

The results in the spalling test for any one brand shall be reported as the average loss of ten specimens selected at random. If desired, the test may be made on only five specimens, but when this is done an additional five specimens shall be tested in the event that the first five do not pass the specifications, and the results reported as the average of the entire ten.

(4) The modulus of rupture shall be determined in accordance with the method of test for modulus of rupture of building brick, as described in Section 75 (A1–C2), Tentative Methods of Testing Brick (Serial Designation C67–27T), A.S.T.M. (See pp. 477–80.)

The results in the modulus of rupture test for any one brand shall be reported as the average of ten specimens selected at random. If desired, the test may be made on only five specimens, but when this is done an additional 5 specimens shall be tested in the event that the first five do not pass the specification, and the results reported as the average of the entire ten.

[1] See p. 461, this issue.

(5) The load test shall be made in accordance with the Standard Method of Test for Refractory Materials under Load at High Temperatures (Serial Designation: C16), A.S.T.M.

NOTE: It will be noted that the present Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (C38–27T) A.S.T.M. is the one referred to in these specifications. It is recognized that there are other methods which have much to commend them; the 850°C water dip spalling test developed at the Bureau of Standards; the air-spalling test used by a large contracting company; and possibly others. It seems very probable, however, in the light of past work and that now going on, that the ultimate spalling test may be different from any of these. Everything considered, it seems best to use Method C38 for the present.

36. CLAY FIRE BRICK FOR STATIONARY BOILER SERVICE

These specifications are intended to cover only fired products made from fire clay by the usual processes of manufacture and containing not more than 55% alumina or 85% silica. Even within this range of composition, it is not intended to include products other than those regularly sold as clay fire brick.

(A) Purpose and Utility of Specifications

The purpose of these specifications is the selection of clay fire brick for general boiler service. They may not apply to the special conditions sometimes encountered in high power utility boilers. In these plants general conditions may not apply and the selection of the refractories often becomes a special problem for the particular plant involved.

Use of the specifications will not relieve the buyer of all responsibility for the selection of the refractories best suited to his particular practice. Of the brands which meet these requirements, some may give highly satisfactory service in one installation and fail to do so in another. Certain brands may give best service in one plant, other brands in another plant. The reason for this variability in service lies in the almost countless combinations of conditions which may exist in boiler furnace operation. Some of the factors which directly or indirectly affect the life of the refractories are the following.

(1) Factors dependent upon design or construction of the setting: (*a*) furnace volume, (*b*) thickness and height of walls, (*c*) use of relieving arches or sectional wall supports, (*d*) degree of insulation, (*e*) provision for air or water cooling of refractories, (*f*) type of stoker arch, (*g*) height of stoker arch above grates or stoker, (*h*) provision for expansion of the brick work, (*i*) care taken and method followed in laying brick, (*j*) character of mortar used in laying brick.

(2) Factors dependent upon fuel and firing: (*a*) hand or mechanical firing, (*b*) type of grate, stoker, or burner, (*c*) character and kind of fuel, (*d*) direction of flame and impingement on brick work, (*e*) char-

acter of ash or fluxing ingredients, (*f*) quantity of ash or fluxing ingredients, and (*g*) fusibility and viscosity of ash.

(3) Factors dependent upon operation: (*a*) air leaks in furnace walls, (*b*) temperature of operation, (*c*) care and promptness in cleaning boiler tubes, (*d*) continuity of operation, (*e*) character of furnace atmosphere, (*f*) violence of temperature fluctuations, (*g*) rate of operation, (*h*) segregation of different sizes of coal on chain grates, (*i*) pressure or draft conditions in furnace, (*j*) care and promptness of making minor repairs, (*k*) method of removing adhering clinker, and (*l*) abrasion of brick work.

In these specifications brick are divided into siliceous and non-siliceous grades, but no other definite requirement is stipulated as to analysis, as no definite relationship between analysis and service has been demonstrated. The pyrometric cone equivalent requirements are well above the temperatures actually attained by the brick work in general boiler practice.

The most important causes of failure are spalling and slag action. The spalling test specified will select brick of satisfactory resistance to thermal shock for general boiler practice. In those installations where exceptionally severe spalling appears to occur, the failure of the brick may in many cases be the result of factors which cannot be measured in a spalling test. Such conditions call for study by a competent engineer.

Brick which are subjected to severe slagging conditions in service should not be required to meet a severe spalling test specification. Although slagging is one of the major causes of failure of the refractories, no test for slag resistance is included in these specifications for the reason that in the light of present knowledge none of the methods of making slag tests that have been proposed can be regarded as satisfactory.

Revision of the requirements is to be expected as methods of testing are further perfected, and as the effect of operating conditions upon the life of the brick becomes better understood. Clay fire brick which fail to meet the requirements of this specification may be regarded, however, as unsuitable for general boiler practice.

(B) Size Tolerance

Variations ($\pm$) of 2% from specified dimensions covering both shrinkage and warpage shall be allowed on dimensions of 4 in., or over. On dimensions under 4 in., 3% variation shall be allowed.

(C) Test Requirements on Moderate Heat Duty Boiler Settings

The requirements for brick for moderate heat duty boiler settings are intended to apply to boiler furnaces in which the temperatures are not over 2400°F (1315°C).

(1) Zone of Highest Temperatures (sidewalls, arches, doors, and jambs):

(*a*) The pyrometric cone equivalent shall not be below cone 29 in the case of the nonsiliceous grade[1] and not below cone 27 in the case of the siliceous grade.[1]

(*b*) When duplicate samples are heated uniformly to a temperature of 1350°C, maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of more than 1.5% of the original length.

(2) Zone of Lower Temperatures (backing-up brick for highest temperature zone, and walls beyond first tube bank):

(*a*) The pyrometric cone equivalent shall not be below cone 18.

(*b*) The modulus of rupture of the brick tested cold shall not be under 500 lb. per sq. in.

(D) Test Requirements on High Heat Duty Boiler Settings

(1) Zone of Highest Temperatures (sidewalls, bridgewalls, arches, doors and jambs; and first pass sidewalls):

(*a*) The requirements for brick for zone of highest temperatures in high heat duty boiler settings are intended to apply to boiler furnaces in which the temperature of the combustion chamber is continuously, or a significant portion of the time, above 2400°F (1315°C) under normal conditions of operation. The refractoriness of the nonsiliceous grade is assured by the softening point, but for this requirement in the case of the siliceous grade it is necessary to incorporate both the pyrometric cone equivalent and load test.

(*b*) The pyrometric cone equivalent shall not be below cone 31 in the case of the nonsiliceous grade and not below cone 28 in the case of the siliceous grade.

(*c*) When duplicate samples are heated uniformly to a temperature of 1400°C maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of the original length of more than 1.5% in the case of the nonsiliceous grade and 0.75% in the case of the siliceous grade.

(*d*) When subjected to the spalling test, brick shall withstand an average of 5 dips in the case of the nonsiliceous grade and 3 dips in the case of the siliceous grade.

(*e*) Deformation in the standard load test at 1350°C under a load of 25 lb. per. sq. in. shall not be over 6% in the case of the siliceous grade.

(2) Service Condition No. 1: For division walls heated on both sides, the following requirements shall apply:

[1] Brick are considered as being of siliceous grade when the silica content is greater than 65% and of nonsiliceous grade when the silica content is 65% or less.

(*a*) The pyrometric cone equivalent shall not be below cone 31 in the case of the nonsiliceous grade and not below cone 28 in the case of the siliceous grade.

Deformation in the standard load test at 1350°C under a load of 25 lb. per. sq. in. shall not be over 6% in the case of the nonsiliceous grade and not over 4% in the case of the siliceous grade.

NOTE: It is not practical to include a spalling test for brick subject to rigid load test requirements.

(3) Service Condition No. 2: Under severe conditions of spalling the following requirements shall apply:

(*a*) The pyrometric cone equivalent shall not be below cone 31 in the case of the nonsiliceous grade and not below cone 28 in the case of the siliceous grade.

(*b*) When duplicate samples are heated uniformly to a temperature of 1400°C, maintained at this temperature for 5 hours and cooled, they shall not show an average contraction of the original length of more than 2% in the case of the nonsiliceous grade and 1% in the case of the siliceous grade.

When subjected to the spalling test, brick shall withstand an average of 9 dips in the case of the nonsiliceous grade and 4 dips in the case of the siliceous grade.

NOTE: It is not practical to include a limit for deformation under load, since fireclay brick which are so made as to give the highest resistance to spalling are relatively weak under load.

(4) Service Condition No. 3: For service where slagging conditions are severe, the following requirements shall apply:

(*a*) The pyrometric cone equivalent shall not be below cone 31 in the case of the nonsiliceous grade and not below cone 28 in the case of the siliceous grade.

(*b*) When duplicate samples are heated uniformly to a temperature of 1400°C, maintained at this temperature for 5 hours, and cooled, they shall not show an average contraction of the original length of more than 1% in the case of the nonsiliceous grade and 0.5% in the case of the siliceous grade.

(*c*) Water absorption shall not be over 10% in the case of the nonsiliceous grade and 18% in the case of the siliceous grade.

NOTE: These tests are specified for conditions of severe slag erosion to insure good refractoriness and high density, as these properties are known to be important. No slag test has been devised which gives quantitative results that can be used in specification.

(5) When any one of the three special service conditions described in Sections 2, 3, and 4 is to be met, it shall be expressly stipulated by the purchaser.

(6) Zone of Lower Temperatures (backing-up brick for highest temperature zone, and walls of second and third passes):

(*a*) The service to which brick in the zone of lower temperatures are subjected varies with the size and type of boiler, thickness of walls, degree of insulation, draft conditions and position in the furnace. Leaky baffles may sometimes cause the brick beyond the first tube bank to be subjected to unexpectedly high temperatures. Depending upon the particular conditions, and upon the margin of safety desired, the brick used may be of the same grade as used in the zone of highest temperatures as described in paragraph (D*a*), or of one of the following grades:

	Grade A	Grade B	Grade C
Softening point, not under	cone 28	cone 26	cone 18
Modulus of rupture, lb. per. sq. in, not under	450	500	500

(E) Test Requirements on Methods of Testing

(1) The determination of silica content shall be made in accordance with the analytical methods described in the Standard Methods of Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick (Serial Designation: C18) A.S.T.M.

(2) The pyrometric cone equivalent shall be determined in accordance with the Standard Method of Test for Pyrometric Cone Equivalent of Fireclay Brick (Serial Designation: C24) A.S.T.M.

In the event that the material fails to pass the specification by one cone or less, two additional pyrometric cone equivalent determinations shall be made as checks on the accuracy of the test and the final results judged on the basis of the three determinations. This procedure is necessary because of variations that have been found to exist in this test even where the standard methods are followed.

(3) The spalling test shall be conducted in accordance with the Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (Serial Designation: C38–27T) A.S.T.M. The test shall be continued until each brick shall have lost 20% by weight or until the total number of immersions necessary to give the required average has been obtained. Individual samples shall not be continued in the test after a loss of 20% has been sustained. The brick shall be dried and weighed before and after testing and the loss computed as a percentage of the original dry weight.

(4) The results in the spalling test for any one brand shall be reported as the average loss of 10 specimens selected at random. If desired, the test may be made on only 5 specimens, but when this is done an additional 5 specimens shall be tested in the event that the first 5 do not pass the specifications, and the results reported as the average of the entire 10.

(5) The modulus of rupture shall be determined in accordance with the method of test for modulus of rupture of building brick, as described in Sections 8 to 12 of the Tentative Methods of Testing Brick (Serial Designation: C67–27T) A.S.T.M. (See pp. 477–80.)

The results in the modulus of rupture test for any one brand shall be reported as the average of 10 specimens selected at random. If desired, the test may be made on only 5 specimens, but when this is done an additional 5 specimens shall be tested in the event that the first 5 do not meet the requirements, and the results reported as the average of the entire 10.

(6) The load test shall be made in accordance with the Standard Method of Test for Refractory Materials under Load at High Temperatures (Serial Designation: C16) A.S.T.M.

NOTE: It will be noted that the present Tentative Method of Test for Resistance of Fireclay Brick to Thermal Spalling Action (C38–27T) of the A.S.T.M. is the one referred to in these specifications. It is recognized that there are other methods which have much to commend them; the 850°C water dip-spalling test developed at the Bureau of Standards; the air-spalling test used by a large contracting company; and possibly others. It seems very probable, however, in the light of past work and that now going on, that the ultimate spalling test may be different from any of these. Everything considered it seems best to use Method C38 for the present.

37. BUILDING BRICK MADE FROM CLAY OR SHALE

(Same as Serial Designation: C62–27T A.S.T.M.)

These specifications cover building brick made from clay or shale and properly fired, suitable for use in the construction of buildings.

(A) Physical Properties and Tests

(1) (*a*) The bricks shall be classified as Grades A, B, and C on the basis of the following requirements. The classification of any lot of bricks shall be determined by the results of the tests for that requirement in which it is lowest, unless otherwise specified as provided in Section 37 (D3), p. 404:

Name of Grade	Compressive Strength (bricks flatwise), lb. per sq. in.		Modulus of Rupture (bricks flatwise), lb. per sq. in.	
	Mean of 5 tests	Individual minimum	Mean of 5 tests	Individual minimum
Grade A	4500 or over	3500	600 or over	400
Grade B	2500–4500	2000	450 " "	300
Grade C	1250–2500	1000	300 " "	200

NOTE: Bricks of Grades A and B are usually hard- or well-fired. Bricks of Grade C are usually underfired.

(*b*) The tests shall be conducted in accordance with the Tentative Methods of Testing Brick (Serial Designation: C67–27T)A.S.T.M.

(2) For the purpose of tests, bricks fairly representative of the commercial product shall be selected by a competent person appointed by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or seller shall furnish specimens for tests without charge. All brick shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than ten brick shall be required for each investigation. In general, two samples of ten brick each shall be tested for every 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, the number of samples tested may be fewer, provided that they shall be distributed as uniformly as practicable over the entire lot. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

(B) Standard Sizes

(1) The standard sizes shall conform to the following dimensions, with a permissible variation, plus or minus, of $^1/_8$ in. in depth, $^1/_{16}$ in. in width, and $^1/_4$ in. in length:

Type	Depth (inches)	Width (inches)	Length (inches)
Common brick	$2^1/_4$	$3^3/_4$	8
Rough-face brick	$2^1/_4$	$3^3/_4$	8
Smooth-face brick	$2^1/_4$	$3^7/_8$	8

(C) Workmanship and Finish

(1) When any particular surface appearance or uniformity is desired, it shall be as mutually agreed upon.

(D) Inspection and Rejection

(1) All brick shall comply with the following requirements for general properties under visual inspection:

(*a*) They shall be free from cracks, warpage, stones, pebbles, or particles of lime that would affect their serviceability or strength.

(*b*) Bricks of Grades A or B when struck together shall give a ringing sound.

(2) If the visual inspection, paragraph (D1), appears to indicate inferior strength, the brick may be rejected unless the physical tests show the quality or grade to be as specified.

(3) At the option of the purchaser, acceptance may be based on the visual inspection requirements specified in paragraph (D1) and the results of one of the strength tests (compression or flexure) specified in Section (A1). While the compressive strength is considered as generally giving the better basis for classification purposes, the flexure test gives important information on the strength and proper manufacturing details.

38. SPECIFICATIONS FOR PAVING BRICK

(Same as Serial Designation: C7-27T A.S.T.M.)

This is a Tentative Standard only, published for the purpose of eliciting criticism and suggestions. It is not a Standard of the AMERICAN CERAMIC SOCIETY and is subject to annual revision; issued, 1927.

(1) These specifications cover all styles of vitrified paving brick used in the construction of pavements, and classified as follows:

Class A Vitrified Paving Brick The sizes and varieties recognized by the Permanent Committee on Simplification of Varieties and Styles for Vitrified Paving Brick of the U. S. Department of Commerce are as follow:

	Depth (inches)	Width (inches)	Length (inches)
Plain wire-cut (vertical fiber lugless as usually laid)	2½	4	8½
	3	"	"
	3½	"	"
Wire-cut lug (Dunn)	4	3½	"
Repressed lug	"	"	"

NOTE: The above sizes and varieties are those recognized by the Permanent Committee, for the year 1927, and are subject to change from year to year.

Class B All other sizes and varieties.

Vitrified Paving Brick (2) The consumer or purchaser shall specify the class and variety or size, or the classes and varieties or sizes of paving brick to be supplied.

(A) Manufacture

(1) (*a*) Paving brick shall be manufactured from fire clay or shale, or a combination thereof.

(*b*) The material shall possess such physical and chemical properties that when molded into brick and properly vitrified, the resulting product will meet the requirements of these specifications.

(B) Physical Properties and Tests

(1) (*a*) In addition to other tests mutually agreed upon, the quality and acceptibility of paving brick, shall be determined by the Rattler Test, as described in the Tentative Methods of Testing Brick (Serial Designation: C67–27T) A.S.T.M., for the purpose of determining whether the brick possesses to a sufficient degree, strength, toughness, and hardness.

(*b*) A visual inspection shall be made for the purpose of determining whether the physical properties of the brick as to dimensions, accuracy, and uniformity of shape and color, are in general satisfactory as well as for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

(*c*) The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

(2) The percentage of loss in the Rattler Test to be taken as the standard is not fixed in these specifications, and shall remain within the contracting parties. For their information, the average percentage of loss as determined in accordance with the Rattler Test in the Tentative Methods of Testing Brick (Serial Designation: C67–27T) A.S.T.M., should not exceed 22% for heavy-traffic brick and 24% for light-traffic brick.

(C) Sampling

(1) The standard test sample of paving brick of any size shall be ten brick.

(2) In general, where a shipment of brick involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, on cars at their destination, or on the street when delivered ready for use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Brick accepted as the result of test prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to culling as specified in paragraph (E1) p. 407.

(3) In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be be rejected by visual inspection as provided in (E1) p. 407, except that where controversy arises, whole tests may be selected to determine the admissibility of certain varieties or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall agree on a disinterested person to select the samples, and both parties shall be bound by the results of tests made on samples thus selected.

(4) In general, one sample of ten bricks shall be tested for every 10,000 bricks contained in the lot under consideration, but where the total quantity exceeds 100,000, the number of samples tested may be fewer than one per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

(5) Samples which must be transported long distances by freight or express shall be carefully put in packages holding not more than twelve bricks each. When more than six bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side

by side, and these rows shall be separated by a partition. In the event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining ten sound undamaged bricks.

(6) Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If they are wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours at a temperature of 38°C (100°F) before testing.

(D) Size and Permissible Variations

(1) Paving brick shall conform to the following size requirements, subject to plus or minus variations of $^1/_8$ in. in width and depth, and $^1/_8$ in. in length:

Class B Brick	Depth (inches)	Width (inches)	Length (inches)
Minimum	2	3	$8^1/_2$
Maximum	4	4	9
Class A Brick			
Minimum	$2^1/_2$	$3^1/_2$	$8^1/_2$
Maximum	4	4	$8^1/_2$

(E) Inspection and Rejection

(1) It shall be the right of the buyer to inspect the brick, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

(*a*) All brick which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them insofar as practicable in obtaining the necessary half-bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

(*b*) All brick which are cracked in such a degree as to produce defects such as are defined in paragraph (*a*), either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, firing, or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

(*c*) All brick which are so off-size, or so misshapen, bent, twisted or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

(*d*) All brick which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between the buyer

and seller under this item, it shall be the right of the buyer to make two or more Rattler Tests of the brick, which he wishes to exclude, as provided in paragraph (B1*a*) and if in either or both tests,[1] the brick fall beyond the maximum rattler losses permitted under the specifications, then all brick having the same objectionable appearance may be excluded, and the seller shall pay the costs of the tests. But, if under such procedure, the bricks which have been tested as objectionable, shall pass the Rattler Test, the percentage of loss in both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay the costs of the tests.

(*e*) All brick which differ so markedly in color from the type or average of the shipment, as to make the resultant pavement checkered or disagreeably mottled in appearance. This requirement shall not be held to apply to the normal variations in color which may occur in the product of one plant among brick which will meet the Rattler Test as provided in (E2) below, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

(2) (*a*) Paving brick shall not be judged for acceptance or rejection by the results of individual tests, but by the average of not less than five tests except that where a lot of brick fails to meet the required average, it shall be optional with the buyer whether the brick shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in paragraph (*c*).

(*b*) Some fluctuation in the results of the Rattler Test, both on account of variations in the bricks and in the machine used in testing, is unavoidable and a reasonable allowance for such fluctuation should be made, wherever the standard may be fixed.

(*c*) In any lot of paving brick, if the percentage of loss on a test computed upon its initial weight exceeds the specified loss by more than 2%, then the portion of the lot represented by that test shall at once be re-sampled and three more tests made; and if any of these three tests shall again exceed by more than 2% the specified loss then that portion of the lot shall be rejected.

If, in any lot of brick, the results of two or more tests exceed the permissible maximum, then the buyer may, at his option, reject the entire lot, even though the average of all the tests executed may be within the required limits.

(*d*) Where a lot, or portion of a lot of brick is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may, at his option, permit

[1] See p. 405.

the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

(3) Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller, whether the material is finally accepted or rejected.

39. SPECIFICATIONS FOR CLAY SEWER PIPE

(Same as Serial Designation: C13–24 A.S.T.M.)

NOTE: (1) These specifications cover clay products intended to be used for the conveyance of sewage, industrial wastes, and storm water.

(2) Sewer pipes furnished under these specifications shall be of a single class to be designated "A.S.T.M. Clay Sewer Pipe."

(A) Material and Manufacture

(1) (*a*) Clay pipes shall be manufactured from surface clay, fire clay, or shale, or a combination of these materials.

(*b*) *Surface clay* is an unconsolidated, unstratified clay,[1] occurring on the surface.

(*c*) *Fire clay* is a sedimentary clay[1] of low flux content.

NOTE: It is usually associated with coal measures.

(*d*) *Shale* is a thinly stratified, consolidated sedimentary clay[1] with well marked cleavage parallel to the bedding.

(*e*) The materials shall possess such physical and chemical properties that when molded into pipes and subjected to a suitable temperature the product will be strong, durable and serviceable, free from objectionable defects, and in compliance with these specifications and tests.

(B) Chemical Tests and Requirements

(1) The consumer or purchaser may prescribe in advance special chemical requirements in cases where industrial wastes have marked acid or alkaline character, or are of abnormally high temperatures.

[1] The definitions for the terms "surface clay," "fire clay," and "shale" are based upon the following definition for the term "clay":

Clay.—An earthy or stony mineral aggregate consisting essentially of hydrous silicates of alumina, plastic when sufficiently pulverized and wetted, rigid when dry, and vitreous when fired at a sufficiently high temperature.

TABLE 1

DIMENSIONS, ETC., OF CLAY SEWER PIPE FURNISHED AS TEST SPECIMENS

Specimen No.	Date	Job No.	Material	Manufacturer	Location of Factory	Nominal Size, in.	Weight, lb.	Length, ft.	Thickness of Spigot, in.				Thickness of Socket, in.				Internal Diameter, in.						Remarks
																	Spigot		Back of Socket		Socket		
									Invert	Crown	Side	Side	Invert	Crown	Side	Side	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	

He may make use of chemical analysis of the pipe material to ascertain whether these special requirements are met. The presence of visible grains or masses of caustic lime, iron pyrites, or any other materials which cause slaking or disintegration shall be a cause for rejection.

(C) Physical Tests

(1) The physical tests of pipes shall include: crushing test, hydrostatic pressure test, and absorption test.

(2) The specimens to be tested shall be selected by the purchaser or his representative at the point or points designated by him when placing the order. The manufacturer or seller shall furnish specimens for test, without separate charge, up to 1% of the number of pipes to be delivered or furnished in each size of pipe, except that in no case shall the number of specimens furnished be less than five.

(3) (*a*) Failure of 20% of the specimens to meet the requirements of any of the tests imposed, shall result in rejection of all the pipe in the shipment or delivery, corresponding to the sizes thus failing to comply; except that in the event of 20% of the specimens in any size failing to meet the requirements, the manufacturer or seller may, with the consent of the consumer or purchaser, furnish for test, without charge, additional specimens from the same shipment to be selected as specified in (C2) above. In case more than 80% of the specimens tested, including those first tested, shall show substantial compliance for each of the various tests performed, then the entire shipment or delivery for this size shall be accepted; otherwise it shall be rejected.

(*b*) In addition to the foregoing requirements, failure of individual specimens to develop 75% of the average crushing strength requirements shall be cause for rejection of the shipment, but the seller may cull the pipe and submit the remainder of the shipment for retest, and, if the shipment then passes all of the requirements of these specifications, it shall be accepted.

(4) The specimens of pipes shall be sound, full-size pipe. They shall first be freed from all visible moisture. When dry, each specimen shall be weighed, measured, and inspected. The results of these observations shall be recorded and preserved as shown in Table I.

(5) Specimens which, when placed in a vertical position, do not give a metallic ring when struck with a hammer, or are observed to have fire cracks or other defects in form or dimensions in excess of the limits permitted in these specifications shall be discarded and replaced with additional specimens from the shipment.

Crushing Tests (1) (*a*) Any prime mover or hand power which will apply the load at a uniform rate of about 2000 lbs. per minute, or in increments of not more than 100 lbs. at the same rate, may be used in making the test.

(*b*) The pipe shall not be allowed to stand under load longer than is required to apply the load and to observe and record it.

(*c*) The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part.

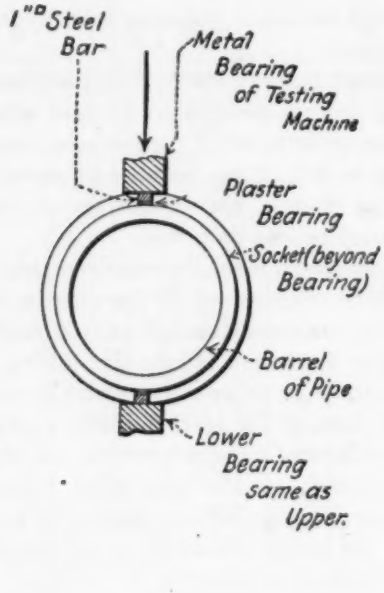


FIG. 1.—Knife or two-edge bearings.

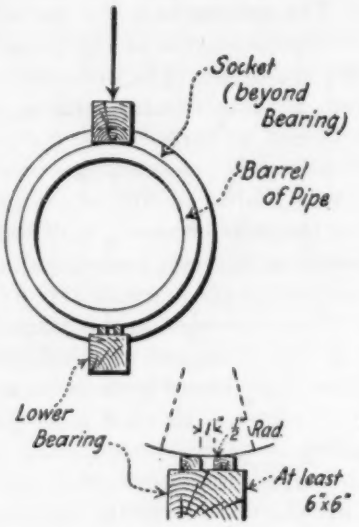


FIG. 2.—Three-edge bearings.

(*d*) The bearings and the specimen shall be accurately centered so as to secure a symmetrical distribution of the loading on each side of the center of the pipe in every direction.

(*e*) The load shall be applied until the pipe yields by cracks passing through the shell.

(2) (See Fig. 1.) Except as otherwise hereinafter specified, the pipe to be tested shall be supported by a metallic knife bearing 1 in. wide and extended from a point just back of the socket to the spigot end of

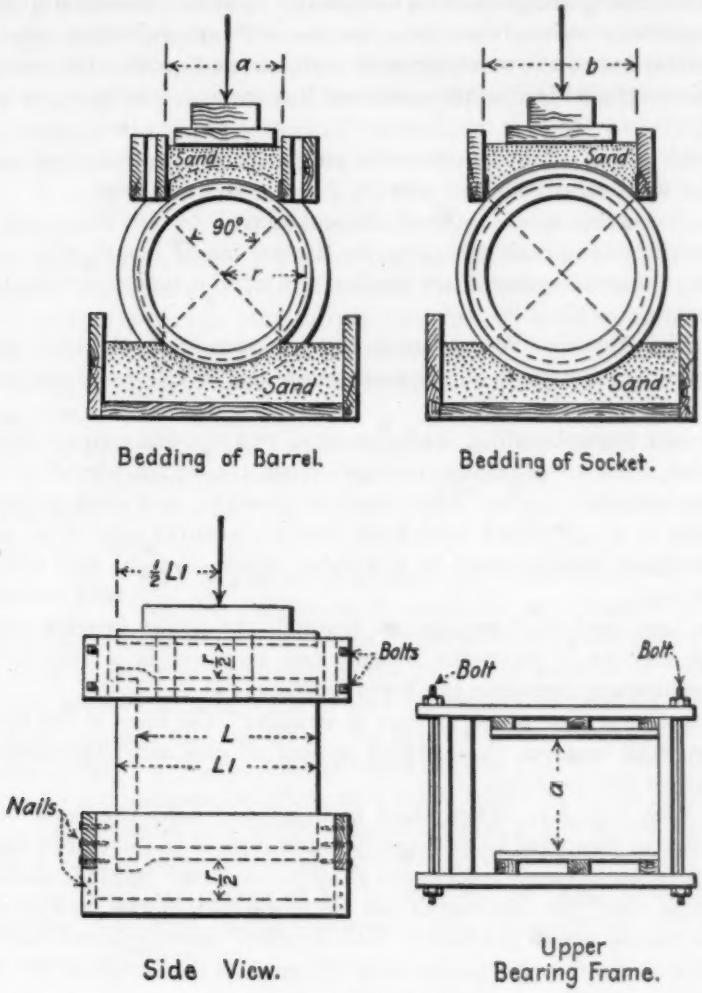


FIG. 3.—Sand bearings.

the pipe. Before the pipe is placed, a fillet of plaster of Paris and sand 1 in. wide, and thick enough to compensate for all the inequalities of the pipe barrel, shall be cast on the surface of the knife-edge bearing. The pipe shall be placed upon the fillet while the plaster of Paris is

still somewhat plastic. The load shall be applied through an upper knife bearing of the same size and length as the lower bearing. A plaster of Paris fillet 1 in. wide shall be cast along the length of the crown of the pipe to equalize the lower bearing before the upper one is brought into contact.

Both of the bearings shall be sufficiently rigid to transmit and receive uniform loads throughout their lengths without deflection, and shall be so attached to the machine as to transmit and receive the maximum stresses produced by the tests without lost motion, vibration, or sudden shock.

At the option of the consumer or purchaser the crushing test may be applied with sand bearings or with 2- or 3-edge bearings.

The crushing strength shall be calculated by dividing the total load required to break each pipe by the net inside length of the barrel of the pipe, measuring from the bottom of the socket to the end of the spigot.

(3) (See Fig. 2.) When 3-edge bearings are used, the ends of each specimen of pipe shall be accurately marked in halves of the circumference prior to the test.

The two lower bearings shall consist of two wooden strips with vertical sides, each strip having its interior top corner rounded to a radius of approximately $^1/_2$ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a pipe which is "out of straight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

(4) (See Fig. 3.) When sand bearings are used the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top-bearing frame shall not be allowed to come in contact with the pipe or with the top-bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall

be covered with a rigid top-bearing plate, with lower surface a true plane made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top-bearing plate in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top-bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top-bearing frame.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side along the lower edge to prevent the escape of sand between the frame and the pipe.

(5) The crushing test shall ordinarily be applied to not less than 75% of the specimens received for testing purposes.

(6) Pieces of the crushed pipe may be used as specimens in making the absorption test.

Hydrostatic Test (1) Sound full-size pipe not exceeding about 25% of the specimens received for test in each size of pipe, shall be tested for leakage under internal hydrostatic pressure.

The ends of the pipe shall be tightly closed by wooden or metallic bulkheads or covers faced with rubber or leather so that no leakage shall occur through the covers at the test pressure. One cover shall be provided with a $^3/_4$-in. wrought-iron nipple passing through the cover, and held securely in place and made water-tight by means of locknuts and washers or gaskets. The outer end of the nipple shall be connected with a pump discharge or water service line.

Water pressure, as measured by a standardized gage attached to the delivery pipe close to the specimen, shall be internally applied to the specimen as follows:

5	lb.	per sq. in	for	5	minutes
10	"	"	"	10	"
15	"	"	"	15	"

The specimens shall show no leakage under these pressures. Moisture appearing on the surface of the pipe in the form of patches or beads, adhering to the surface, shall not be considered leakage.

Absorption Test (1) The specimens shall be sound pieces, with all edges broken, and may be from pipes broken in the crushing or other tests. They shall be from 12 to 20 sq. in. in area, and shall be as nearly square as they can be readily prepared. They shall be free from observable cracks, fissures, laminations, or shattered edges.

(2) Preparatory to the absorption test, the specimen shall be first weighed and then dried in a drier or oven at a temperature of not less than 110°C (230°F) for not less than three hours. After removal from the drier, the specimen shall be allowed to cool in dry air to a temperature of 20 to 25°C (68 to 77°F), and then reweighed.

If the specimen is comparatively dry when taken, and the second weight closely agrees with the first, it shall be considered dry. If the specimen is wet when taken it shall be placed in the drier for a drying treatment of two hours and reweighed. If the third weight checks the second the specimen shall be considered dry. In case of any doubt, the specimen shall be redried for two-hour periods, until check weights are obtained.

(3) The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read to the nearest gram. When other than metric weights are used, the same degree of accuracy shall be obtained.

(4) The specimen, after final drying, cooling and weighing, shall be placed with other similar specimens in a suitable wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15°C (50 to 59°F).

(5) The specimen shall be allowed to drain for one minute, and the superficial moisture having been removed by towel or blotting paper, placed upon the balance.

(6) The test result shall be calculated as percentage of the initial dry weight.

(7) One specimen shall be tested of each pipe broken in the crushing test.

(8) The results shall be reported separately for each individual specimen, together with the mean for all the specimens from the same shipment of pipe.

(9) Each specimen shall be marked so that it may be identified with the pipe used in the crushing test from which the specimen was taken. The marking shall be applied so that the pigment used shall not cover more than 1% of the total superficial area of the specimen.

(D) Physical Test Requirements

(1) The test requirements of clay sewer pipe shall be as given in Table II. The individual results of the various tests for each size of pipe and for each shipment class and mill shall be tabulated separately so as to show the percentage which fails to comply with the requirements of each test.

(E) A.S.T.M. Sizes and Dimensions

(1) Pipes shall be furnished of the sizes, internal diameter, and with the dimensions given in Tables III and IV. Where several lengths are mentioned in the table the consumer or purchaser shall indicate, at the time of purchase, which lengths shall be furnished; and unless so indicated, the manufacturer shall furnish such lengths as he may elect.

(2) The permissible variation from the dimensions given in Table III shall not exceed those stated in Table IV. Where the thickness of barrel is increased beyond that given in Table IV in order to meet the specified requirements of strength, the diameter at inside of socket shall be increased by double the increase in thickness of barrel. Pipes intended to be straight shall not have variation in alignment of more than $^1/_8$ in. per foot of length.

(F) Workmanship and Finish

(1) Pipes shall be substantially free from fractures, large or deep cracks and blisters, laminations, and surface roughness.

TABLE II

PHYSICAL TEST REQUIREMENTS OF CLAY SEWER PIPE

Internal Diameter, in.	Average Crushing Strength, lb. per lin. foot. Knife-Edge[1] and Three-Edge[2] Bearings	Sand Bearings[3]	Maximum Absorption (per cent)
4	1000	1430	8
6	1000	1430	8
8	1000	1430	8
10	1100	1570	8
12	1200	1710	8
15	1370	1960	8
18	1540	2200	8
21	1810	2590	8
24	2150	3070	8
27	2360	3370	8
30	2580	3690	8
33	2750	3930	8
36	3080	4400	8
39	3300	4710	8
42	3520	5030	8

[1] See paragraph (2) p. 413. [2] See paragraph (3) p. 414. [3] See paragraph (4) p. 414.

(2) The inner surface of the socket and the outer surface of the spigot end shall be scored by triangular shaped or semicircular shaped rings about $^1/_8$ in. deep.

The number of scorings shall be as follows:

For pipes	4	to	6	in. in internal diameter, inclusive				none
" "	8	"	10	"	"	"	"	2
" "	12	"	21	"	"	"	"	3
" "	24	"	30	"	"	"	"	4
" "	33	"	42	"	"	"	"	5

(3) The glaze shall consist of a continuous layer of bright or semi-bright glass substantially free from coarse blisters and pimples. If present, none of these shall project more than $^1/_8$ in. above the surrounding surface. Not more than 10% of the inner surface of any pipe barrel shall be bare of glaze except the socket, where it may be entirely absent. Glazing will not be required on the outer surface of the barrel at the spigot end for a distance from the end equal to two-thirds the specified depth of socket for the corresponding size of pipe. Where glazing is required there shall be absence of any well-defined net work of crazing lines or hair cracks. All glazing shall be equal to that produced by the best salt-glazing process.

(4) The ends of the pipes shall be square with their longitudinal axis, except as provided in Table IV.

TABLE III

DIMENSIONS OF CLAY SEWER PIPE

Internal Diameter (D), in.	Laying Length (L), ft.	Inside Diameter at Mouth of Socket (D_s), in.[1]	Depth of Socket (L_s), in.	Minimum Taper of Socket (H)	Thickness of Barrel (T_s), in.	Thickness of Socket (T_s)
4	2	6	$1^1/_2$	1:20	$^9/_{16}$	The thickness of the socket $^1/_4$ in. from its outer end shall not be less than three-fourths of the thickness of the barrel of the pipe
6	2	$8^1/_4$	2	1:20	$^5/_8$	
8	2, $2^1/_2$, 3	$10^3/_4$	$2^1/_4$	1:20	$^3/_4$	
10	2, $2^1/_2$, 3	13	$2^1/_2$	1:20	$^7/_8$	
12	2, $2^1/_2$, 3	$15^1/_4$	$2^1/_2$	1:20	1	
15	2, $2^1/_2$, 3	$18^3/_4$	$2^1/_2$	1:20	$1^1/_4$	
18	2/$2^1/_2$, 3	$22^1/_4$	3	1:20	$1^1/_2$	
21	2, $2^1/_2$, 3	26	3	1:20	$1^3/_4$	
24	2, $2^1/_2$, 3	$29^1/_2$	3	1:20	2	
27	$2^1/_2$, 3	$33^1/_4$	$3^1/_2$	1:20	$2^1/_4$	
30	$2^1/_2$, 3	37	$3^1/_2$	1:20	$2^1/_2$	
33	$2^1/_2$, 3	$40^1/_4$	4	1:20	$2^5/_8$	
36	$2^1/_2$, 3	44	4	1:20	$2^3/_4$	
39	$2^1/_2$, 3	$47^1/_4$	4	1:20	$2^7/_8$	
42	$2^1/_2$, 3	51	4	1:20	3	

[1] When pipes are furnished having an increase in thickness over that given in last column, the diameter of socket shall be increased by an amount equal to twice the increase of thickness of barrel.

(5) (*a*) Special shapes shall have a plain spigot end and a socket end corresponding in all respects with the dimensions specified for pipes of the corresponding internal diameter. Branch pipes shall be furnished to lay the same lengths as straight pipe. All specials shall conform in finish to the specifications for pipes given in paragraphs (1), (2), (3), and (4) above.

(*b*) Slants shall have their spigot ends cut at an angle of approximately 45° with the longitudinal axis.

(*c*) Curves shall be at angles of 90, 45, $22^1/_2$°, as required. They shall conform substantially to the curvature specified.

(*d*) Branches shall be furnished with the connection or connections of the size or sizes specified, securely and completely fastened by fusion in the process of vitrification to the barrel of the pipe. T-branches and double T-branches shall have their axes perpendicular to the longitudinal axis of the pipe. Y-branches, double Y-branches, and V-branches shall have their axes approximately 45° from the longitudinal axis of the pipe measured from the socket end. All branches shall terminate in sockets and the barrel of the branch shall be of sufficient length to permit making a proper joint when the connecting pipe is inserted in the branch socket.

(*e*) Channel or split pipes, curves and branches shall be accurate half-sections of the corresponding size of straight pipe and specials.

(G) Markings

(1) Pipes shall bear the initials or name of the person, company or corporation by whom they are manufactured, and the location of the mill. The markings shall be indented on the exterior of the barrel near the socket and shall be plainly legible for purpose of identification.

TABLE IV

PERMISSIBLE VARIATIONS IN DIMENSIONS OF CLAY SEWER PIPE

Normal Size in.	Limits of Permissible Variation					
	Length in. per ft. (−)	Lengths of Two Opposite Sides, in.	Internal Diameter, in.		Depth of Socket, in. (−)	Thickness of Barrel, in. (−)
			Spigot (±)	Socket (±)		
4	1/4	1/8	1/8	3/16	1/8	1/16
6	1/4	1/8	3/16	1/4	1/4	1/16
8	1/4	1/8	1/4	5/16	1/4	1/16
10	1/4	1/8	1/4	5/16	1/4	1/16
12	1/4	1/8	5/16	3/8	1/4	1/16
15	1/4	1/8	5/16	3/8	1/4	3/32
18	1/4	3/16	3/8	7/16	1/4	3/32
21	1/4	3/16	7/16	1/2	1/4	1/8
24	3/8	1/4	1/2	9/16	1/4	1/8
27	3/8	1/4	5/8	11/16	1/4	1/8
30	3/8	1/4	5/8	11/16	1/4	1/8
33	3/8	3/8	3/4	13/16	1/4	3/16
36	3/8	3/8	3/4	13/16	1/4	3/16
39	3/8	3/8	3/4	13/16	1/4	3/16
42	3/8	3/8	3/4	13/16	1/4	3/16

NOTE.—The minus sign (−) alone indicates that the plus variation is not limited, the plus and minus sign (±) indicates variation in both excess and deficiency in dimension.

(H) Inspection

(1) All pipes shall be subject to inspection at the factory, trench, or other point of delivery by a competent inspector employed by the

consumer or purchaser. The purposes of the inspection shall be to cull and reject pipes which, independent of the physical tests herein specified, fail to comply with the requirements of these specifications.

(2) Pipes shall be subject to rejection on account of the following:

(*a*) Variations in any dimension exceeding the permissible variations given in Table IV.

(*b*) Fracture or cracks passing through the shell or socket, except that a single crack at either end of a pipe not exceeding 2 in. in length or a single fracture in the socket not exceeding 3 in. in width or 2 in. in length will not be deemed cause for rejection unless these defects exist in more than 5% of the entire shipment or delivery.

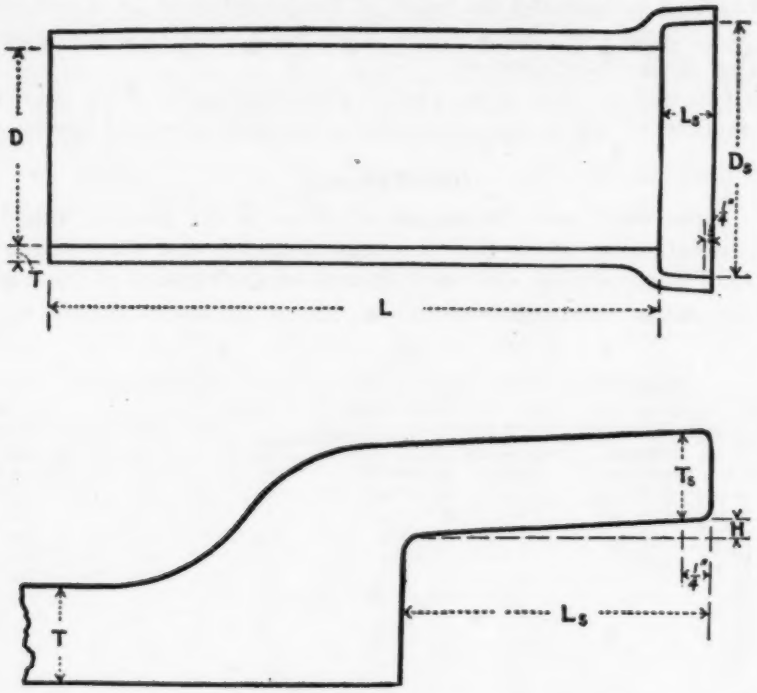


FIG. 4.—Application of dimensions given in Table III.

(*c*) Blisters where the glazing is broken or which exceed 3 in. in diameter, or which project more than $^1/_8$ in. above the surface.

(*d*) Laminations which indicate extended voids in the pipe material.

(*e*) Fire cracks or hair cracks sufficient to impair the strength, durability or serviceability of the pipe.

(*f*) Variation of more than $^1/_8$ in. per linear foot in alignment of a pipe intended to be straight.

(*g*) Glaze which does not fully cover and protect all parts of the shell and ends except those exempted in paragraph (3) p. 418; also glaze which is not equal to best salt glaze.

(*h*) Failure to give a clear ringing sound when placed on end and dry-tapped with a light hammer.

(*i*) Insecure attachment of branches on spurs.

(3) All rejected pipes shall be plainly marked by the inspector and shall be replaced by the manufacturer or seller with pipes which meet the requirements of these specifications, without additional cost to the consumer or purchaser.

40. SPECIFICATIONS AND TESTS FOR HOLLOW FIRED-CLAY LOAD-BEARING WALL TILE

(Same as Serial Designation: C34–27 A.S.T.M.)

(1) These specifications apply to hollow load-bearing wall tile made from surface clay, shale, fire clay, or admixtures thereof.

(A) Classification

(1) According to the results of physical tests, tile shall be classified as hard, medium, and soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:[1]

Class	Absorption, per cent		Compressive Strength, Based on Gross Area, lb. per sq. in.*			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	2000 or more	1400	1000 or more	700
Medium	16 or less	19	1400 or more	1000	700 or more	500
Soft	25 or less	28	1000 or more	700	500 or more	350

* Gross area shall be taken as the total area inclosed by the outside dimensions of the unit taken in a direction perpendicular to that in which the load is carried.

(2) Where end-construction tile are used on the side they shall meet the requirements of that construction, and *vice versa*.

(3) All tile shall be so designed that substantially the same masonry strength will be developed in all wall thicknesses for which they are to be used.

(B) Weights

(1) The tile shall have the following dry weights determined as hereinafter specified:

[1] As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

Size of Unit, in.	Number of Cells	Standard Weight, lb.
3¾ by 12 by 12	3	20
6 by 12 by 12	6	30
8 by 12 by 12	6	36
10 by 12 by 12	6	42
12 by 12 by 12	6	48
12 by 12 by 12	9	52
3¾ by 5 by 12	1	9
8 by 5 by 12	2	16
8 by 5 by 12	3	16
8 by 5 by 12 ("L" Shaped)	–	16
8 by 6¼ by 12 ("T" Shaped)	4	16
8 by 7¾ by 12 (Square)	6	24
8 by 10¼ by 12 ("H" Shaped)	7	32
8 by 8 by 8 (Cube)	9	18

(2) A tolerance of 5% will be allowed on the above standard weights.

(C) Dimensions

(1) No dimension shall vary more than 3% from the standard dimensions for any form of tile.

(D) Weathering Resistance

(1) All tile used in exterior work subjected to weathering conditions shall be able to withstand 100 alternate freezings and thawings. Tile classed as hard or medium by these specifications may be considered as meeting the weathering requirement, provided they are fired to the normal maturity for the given clay. Tile classed as soft shall be accepted as meeting the weathering requirement only on the basis of freezing tests.

(E) Fire Resistance

(1) The tile shall meet the following requirements as tested according to the Tentative Specifications for Fire Tests of Building Construction and Materials (Serial Designation: C19–26T) A.S.T.M.[1] as they apply for bearing walls and partitions and to be acceptable shall develop the following resistance periods as tested unplastered:

Thickness of Wall, in.	Number of Units in Wall Thickness	Number of Cells in Wall	Resistance Period Hours*
8	1	2	1½
8	1	3	2
12	1	3	3
12	2	3	4
12	2	4	5
16	2 or 3	4	6
16	2 or 3	6	8

* These are near the minimum values developed in tests. The average results will generally be higher. Plaster coatings ¾ in. thick applied on both sides and remaining in place throughout the fire test will increase the periods by 1 to 2 hours.

[1] *Proceedings*, A.S.T.M., **26**, [1] 761 (1926); also 1927 Book of A.S.T.M. Tentative Standards.

(F) Workmanship and Finish

(1) All tile shall be well fired, reasonably free from laminations and from such cracks, blisters, surface roughness, and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

(2) The exterior surface of all tile intended for plaster or stucco shall be scored in such a manner as to give good adhesion.

(G) Marking

(1) All tile shall bear the word "Load-Bearing" and initials, name, or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

(H) Inspection and Rejection

(1) Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified in the contract. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed.

(2) Individual tile shall be rejected for failure to meet the weight, size, or workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the seller. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

(3) Except as specified in paragraph (H2) above, and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

(I) Sampling

(1) Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases.

(2) For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. Samples for the freezing tests shall be taken from tile that have not been subjected to strength or fire tests.

(3) Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified. If the fire or freezing tests are to be made it shall be so specified at the time of placing the order, samples for fire tests being selected at the factory at least 45 days in advance of the time of filling the order and 90 days in advance for freezing tests.

(4) All tile selected for test shall be plainly and permanently marked for reference by the testing operator.

(J) Weight Determinations

(1) The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100°C (212°F) and be weighed separately. The scale shall be sensitive to within 0.5% of the weight of the smallest unit.

(K) Strength Tests

(1) Five full-size dry tile shall be used.

(2) The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute.

(3) A spherical bearing block of proper design shall be placed on top of the test sample.

(4) (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of Portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plane surface which has been coated with oil, and allowed to harden sufficiently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $^1/_8$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. If the tile so capped fail to pass specification requirements on the score of strength, they shall be retested with Portland-cement-gypsum caps aged not less than three days.

(5) When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the

tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped.

(6) All tile shall be tested in a position such that the load is applied in the same direction as in service.

(L) Absorption Tests

(1) The samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used, two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. ($^1/_2$ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

(2) Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5% of the total superficial area of the piece shall be used.

(3) Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100°C (212°F).

(4) The balance used shall be sensitive to within 0.2% of the weight of the smallest unit or piece tested.

(5) After obtaining the dry weight of the samples they shall be immersed in soft, distilled, or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature.

(6) After saturation, the samples shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately.

(7) The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile

(M) Freezing Tests

(1) Where the freezing test is to be made, five separate representative tile shall be selected.

(2) If not possible to use the whole tile, a piece consisting of a cell not less than 4 in. long shall be sawed from the tile. These pieces shall be saturated by immersion in cold water for at least 72 hours prior to starting the freezing.

(3) Any practical method of obtaining alternate freezings and thawings may be used, the freezings to be always made with fully saturated samples and the time and temperature to be such as to insure

full freezing and thawing throughout the specimen. The initial weighing and all weighings for loss shall be made on dry specimens.

(4) The balance used shall be sensitive to within 0.1% of the weight of the smallest unit or piece tested.

(5) Failure under the freezing and thawing treatment shall be considered to be reached when:

(*a*) The samples show superficial disintegration or spalling with loss of weight of more than 5% of the initial weight; or

(*b*) The samples are badly cracked; or

(*c*) The samples show evident loss of structural strength.

41. SPECIFICATIONS AND TESTS FOR HOLLOW FIRED-CLAY FLOOR TILE[1]

(Serial Designation: C57–27 A.S.T.M.)

(1) These specifications apply to hollow floor tile made from surface clay, shale, fire clay or admixtures thereof.

(A) Classification

(*a*) According to the results of physical tests, tile shall be classified as hard, medium, and soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:[2]

Class	Absorption, per cent		Compressive Strength Based on Net Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	4600 or more	3000	2400 or more	1700
Medium	16 or less	19	3200 or more	2250	1600 or more	1100
Soft	25 or less	28	2000 or more	1400	1200 or more	850

(*b*) Where end-construction tile are used on the side they shall meet the requirements of that construction, and *vice versa*.

(B) Weights

(*a*) The tile shall have the following dry weights determined as hereinafter specified:

FLAT ARCH

Depth of Arch, in.	Average Weight per Square Foot of Floor, lb.
6	26
7	29
8	32
9	35
10	38
12	42
15	50

[1] Under the standardization procedure of the A.S.T.M., these specifications are under the jurisdiction of the A.S.T.M. Committee C10 on Hollow Masonry Building Units.

[2] As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

SEGMENTAL ARCH

Depth of Arch, in.	Average Weight per Square Foot of Floor, lb.
6	30
8	36
10	40

TILE FOR USE IN COMBINATION HOLLOW TILE AND CONCRETE CONSTRUCTION

Size of Unit, in.	Minimum Number of Cells	Standard Weight, lb.
4 by 12 by 12	3	16
6 " " "	3	22
6 " " "	4	25
8 " " "	"	30
10 " " "	"	35
12 " " "	"	40

(*b*) A tolerance of 5% will be allowed on the above standard weights.

(C) Dimensions

(1) No dimension shall vary more than 3% from the standard dimensions for any form of tile.

(D) Fire Resistance

(1) In cases where the fire resistance is an essential property the purchaser shall specify the degree of fire resistance (fire-resistance period) required, and the manufacturer shall supply such available information on the fire test performance of the given or closely similar product as will aid the purchaser in deciding whether the requirements are met. Further tests in accordance with the Tentative Specifications for Fire Tests of Building Construction and Materials (Serial Designation: C19–26T A.S.T.M.[1] may be conducted by the purchaser.

(E) Workmanship and Finish

(1) All tile shall be well fired, reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would interfere with the proper setting of the tile or impair the strength or permanence of the construction.

(2) The exterior surface of all tile intended for plaster shall be scored in such a manner as to give good adhesion.

(F) Marking

(1) All tile shall bear the initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

(G) Inspection

(1) Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may

[1] *Proceedings*, A.S.T.M., **26** [1], 761 (1926), also 1927 Book of A.S.T.M. Tentative Standards.

be specified. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed.

(2) (*a*) Individual tile shall be rejected for failure to meet the weight, size, or workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the seller. In case the second set of samples fails to meet the test requirements the entire lot shall be rejected.

(*b*) By agreement, acceptance may be based on dry weight of the units, percentage absorption, fire resistance and the workmanship and finish.

(3) Except as specified in paragraph (2*a*) above and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser.

(H) Sampling

(1) Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases.

(2) For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. Where tile of several designs are used, enough samples shall be weighed to determine the true average weight in pounds per square foot for the construction. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. Samples for the freezing tests shall be taken from tile that have not been subjected to strength or fire tests.

(3) Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified in the contract. If the fire tests are to be made, it shall be so specified at the time of placing the order, samples being selected at the factory at least 45 days in advance of the time of filling the order.

(4) All tile selected for test shall be plainly and permanently marked for reference by the testing operator.

(I) Weight Determinations

(1) The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100°C (212°F) and be weighed separately. The scale shall be sensitive to within 0.5% of the weight of the smallest unit.

(J) Strength Tests

(1) Five full-size dry tile shall be used.

(2) The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute.

(3) A spherical bearing block of proper design shall be placed on top of the test sample.

(4) (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of Portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plane surface which has been coated with oil, and allowed to harden sufficiently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $^1/_8$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. If the tile so capped fail to pass specification requirements on the score of strength, they shall be retested with Portland-cement-gypsum caps aged not less than three days.

(5) When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped.

(6) All tile shall be tested in a position such that the load is applied in the same direction as in service.

(L) Absorption Tests

(1) Samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. ($^1/_2$ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests.

(2) Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not

cover more than 5% of the total superficial area of the piece shall be used.

(3) Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100°C (212°F).

(4) The balance used shall be sensitive to within 0.2% of the weight of the smallest unit or piece tested.

(5) After obtaining the dry weight of the samples they shall be immersed in soft, distilled or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature.

(6) After saturation, the sample shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately.

(7) The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile.

42. SPECIFICATIONS FOR DRAIN TILE

(Serial Designation: C4–24 A.S.T.M.)

(A) Classes

(1) (*a*) These specifications cover three classes of drain tile, namely: farm drain tile, standard drain tile, and extra-quality drain tile.

(*b*) The purposes for which these classes are intended to be suitable are as follows:

Farm drain tile, for ordinary private drainage work on farms, for moderate sizes and depths;

Standard drain tile, for ordinary district land drainage at moderate depths;

Extra-quality drain tile, for district land drainage, for considerable depths and where an extra quality is desired.

(2) The purchaser shall specify the class or classes of tile to be supplied, whether farm drain tile, standard drain tile, or extra-quality drain tile. Standard drain tile shall be supplied where no other advance selection is stated.

(3) (*a*) The acceptability of drain tile shall be determined (1) by the results of the chemical and physical tests hereinafter specified, and (2) by visual inspection, to determine whether the tiles comply with the specifications as to dimensions, shape, and freedom from visible external and internal defects.

(*b*) The acceptance of drain tile as satisfactorily meeting one of these two general requirements shall not be construed as in any way waiving the other.

(B) Materials and Manufacture

(1) (*a*) These specifications shall apply to drain tile made of shale, fire clays, or surface clays and to drain tile made of concrete.

(*b*) *Shale* is a thinly stratified, consolidated sedimentary clay with well-marked cleavage parallel to the bedding.

(*c*) *Fire clay* is a sedimentary clay of low flux content.

NOTE: It is usually associated with coal measures.

(*d*) *Surface clay* is an unconsolidated, unstratified clay, occurring on the surface.

(*e*) By concrete is meant a suitable mixture of Portland cement, mineral aggregates, and water, hardened by hydraulic chemical reaction.

(*f*) If the purchaser desires to exclude any of these materials he shall so specify in advance. All materials used shall be first-class of their kind and suitable for the purpose.

(2) The method of manufacture shall be such as to insure excellence of product and uniformity in quality.

(C) Chemical Tests and Requirements

(1) The purchaser may specify special chemical requirements as to resistance of the tile to chemical action in cases where soils or drainage waters have marked acid or alkaline character, or are of abnormally high temperature, and may prescribe chemical tests of the tile to ascertain whether these special requirements are met. Without a special agreement in advance, no drain tile shall be rejected by reason of its composition as determined by ultimate chemical analysis.

The presence in drain tile of visible grains or masses of caustic lime, iron pyrites, or any other minerals which are known to cause slaking or disintegration of the tile, shall be construed as a valid ground for rejection, unless satisfactory proof be submitted that the tiles are permanent and durable, and that the objectionable minerals are not present in quantity or condition to work damage.

(D) Physical Tests

(1) The physical tests of drain tile shall include (*a*) strength tests and (*b*) absorption tests; and may include (*c*) freezing and thawing tests, when specified by the purchaser in advance, or when called for by the manufacturer or other seller as provided in Section 42 (E3–4) p. 437, (F11) p. 440, and (G4) p. 441.

(2) The specimens of tile shall be selected at the factory or at the shipping destination, or at the trench, at the option of the purchaser. The selection shall be made by a competent inspector employed by the purchaser. The inspector shall divide the tile into subclasses if lack of uniformity in any important particular warrants such division, and shall select enough representative specimens of tile from each subclass for a complete set of standard physical tests.

(3) A standard physical test shall comprise tests of five individual tiles. Specimens of tile may be selected by the inspector in such number as he judges necessary to determine fairly the quality of all the tile. The manufacturer or other seller shall furnish specimens of tile without separate charge up to 0.5% of the whole number of tile, and the purchaser shall pay for all in excess of that percentage at the same rate as for other tile.

Strength Tests

(1) The specimens of tile shall be unbroken, full-size tile.

(2) The walls of the tile shall, at the time of testing, be as thoroughly wet as will result from completely covering with hay, cloth, or similar absorbent material, and keeping the covering wet for not less than 12 hours.

(3) No specimen of tile shall be exposed to water or air temperatures lower than 40°F from the beginning of wetting until tested. Frozen tile shall be completely thawed before the wetting begins.

(4) Each specimen of tile shall be weighed on reliable scales just prior to testing, and the weights shall be reported.

(5) Any machine or hand method which will apply the load continuously, or in increments not exceeding 5% of the estimated total breaking load, may be used in making the test. The tile shall not be allowed to stand under load longer than is required for observing and recording the loads. All solid parts of the bearing frames and bearing blocks shall be so rigid that the distribution of the load will not be affected appreciably by the deformation of any part. All bearings and the specimens of tile shall be so accurately centered as to secure a symmetrical distribution of the loading on each side of the center of the tile in every direction.

(6) The purchaser shall choose (1) sand bearings, (2) two-edge bearings, or (3) three-edge bearings, for use in making strength tests of drain tile. (See paragraphs (9), (10), and (11) pp. 433–35.)

(7) The test results shall be calculated and reported, in pounds per linear foot of tile, in terms of the "Ordinary Supporting Strength."[1]

[1] The "ordinary supporting strength," when calculated as specified in paragraph (7), is approximately equal to the actual supporting strength of a tile when laid in a ditch by the "ordinary" method. See note under Table II, p. 438.

The ordinary supporting strength shall be calculated by multiplying the test breaking loads by the following factors: For sand bearings, 1.00; for two-edge bearings, 1.50; for three-edge bearings, 1.50.

The results of the strength tests shall be reported separately for each of the five individual specimens of tile constituting a standard test, together with the average.

(8) The modulus of rupture may or may not be calculated and reported, at the option of the purchaser. When reported it shall be calculated by the equations:[1]

$$M = 0.20r\frac{W}{12} \quad (1)$$

$$f = \frac{6M}{t^2} \quad (2)$$

where M = maximum bending moment in wall in pound-inches per inch of length, r = radius of middle line of tile wall in inches, W = ordinary supporting strength, calculated as prescribed in paragraph (7) above, in pounds per linear foot of tile, f = modulus of rupture in pounds per square inch, and t = thickness of tile wall in inches.

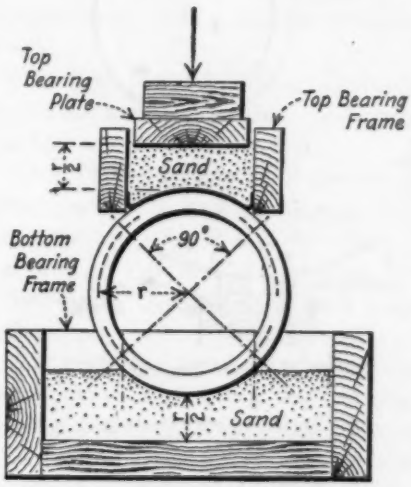


FIG. 1.—Sand bearings.

Five-eighths of the weight of the tile per linear foot for sand bearings, or three-fourths for two-edge or three-edge bearings, shall be added to W in computing the maximum bending moment M, when such addition exceeds 5% of W. The value of t used shall be the average thickness of the wall at the top of the tile or that at the bottom, selecting the lesser of the two.

(9) (See Fig. 1.) When sand bearings are used, the ends of each specimen of tile shall be accurately marked in quarters of the circumference prior to the test. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the tile measured on the middle line of the wall. The depth of bedding above and below the tile at the thinnest points shall be one-half the radius of the middle line of the wall.

[1] The coefficient of 0.20 in equation (1) approximates the value found by theoretical analysis and also that determined by extended tests.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top-bearing frame shall not be allowed to come in contact with the tile or with the top-bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top-bearing plate, in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles

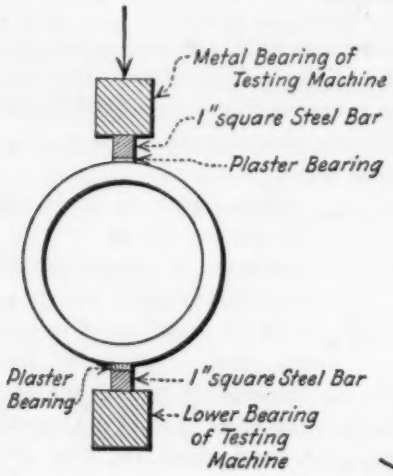


FIG. 2.—Two-edge bearings.

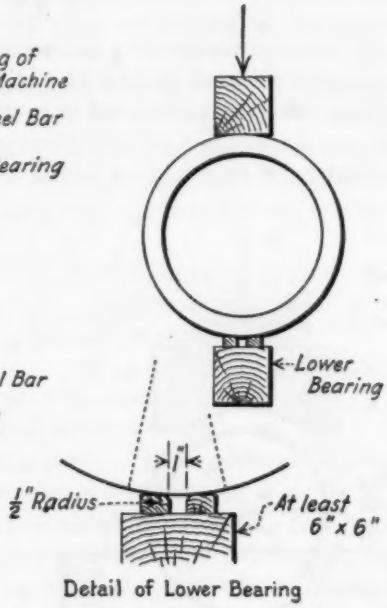


FIG. 3.—Three-edge bearings.

may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top-bearing plate, provided, however, that the weight shall be piled symmetrically about a vertical line through the center of the tile, and that the platform shall not be allowed to touch the top-bearing frame.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of the sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the tile during the test. A strip of cloth may,

if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the tile.

(10) (See Fig. 2.) When two-edge bearings are used, the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

The tile to be tested shall be supported by a metallic knife bearing 1 in. wide and extending the length of the tile. Before the tile is placed, a fillet of plaster of Paris and sand 1 in. wide, and thick enough to compensate for all the inequalities of the tile barrel, shall be cast on the surface of the knife-edge bearing. The tile shall be placed upon the fillet while the plaster of Paris is still somewhat plastic. The load shall be applied through an upper knife bearing of the same size and length as the lower bearing. A plaster of Paris fillet 1 in. wide shall be cast along the length of the crown of the tile to equalize the lower bearing before the upper one is brought into contact.

Both of the bearings shall be sufficiently rigid to transmit and receive uniform loads throughout their lengths without deflection, and shall be so attached to the machine as to transmit and receive the maximum stresses produced by the test without lost motion, vibration, or sudden shock.

(11) (See Fig. 3.) When three-edge bearings are used, the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

The lower bearings shall consist of two wooden strips with vertical sides, each strip having its interior top corner rounded to a radius of approximately $^1/_2$ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a tile which is "out of straight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

Absorption Tests (1) Not less than three separate test specimens from each of five separate tiles shall be taken as a "standard sample" for the absorption test. Of the three specimens from each tile, one shall be taken from one end, another from the opposite end, and the third shall be taken from the middle portion of the tile. Each specimen shall be from 12 to 20 sq. in. in area, measured upon the exterior or convex side, and shall be as nearly square as the nature of the

material will readily permit. The specimens shall be obtained by breaking the tile, and shall be apparently sound, solid pieces of the wall of the tile, and shall not show cracks or fissures or shattered edges due to the shock of breaking or cutting. The specimens may be obtained from the broken pieces of the tile used in the strength test, if the restrictions as to the size and location of the specimens can be duly observed. The specimens shall be so marked as to permit the identity of each one to be ascertained at any stage of the test.

(2) Preparatory to the absorption test, all specimens shall be first weighed and then dried in a drier or oven, at a temperature of not less than 110°C (230°F) for not less than three hours. After removal from the drier, the specimens shall be allowed to cool to a temperature of 20 to 25°C (68 to 77°F) and reweighed. If the specimens were apparently dry when taken, and the second weight closely checks the first, the specimens shall be considered dry. If the specimens were known to be wet when taken, they shall be placed in the drier for a further drying treatment of two hours and reweighed. If the third weight checks the second, the specimens shall be considered dry. In case of any doubt, the specimens must be redried for two-hour periods until check weights are obtained.

(3) The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same order of accuracy must be obtained.

In reweighing after immersion, the specimens shall be removed from the water, not allowed to drain for more than one minute, the superficial water removed by towel or blotting paper, and the specimens at once put upon the balance.

(4) Specimens after weighing shall be placed in a suitable woven-wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15°C (50 to 59°F).

(5) The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each individual specimen, together with the mean of the fifteen or more specimens comprising the standard sample, the maximum and the minimum single observations entering into the mean, and the variation between the maximum and the minimum of the three specimens of each tile represented in the standard sample.

(E) Physical Test Requirements

(1) The physical test requirements for the different classes of drain tile shall be as given in Table I.

(2) Drain tile made of mixtures of surface clays with other clays shall conform to the absorption requirements for surface-clay tile in Table I, when the proportion of surface clay is 75% or more, and to the requirements for shale and fireclay tile for all other proportions.

(3) In the event that a standard sample, paragraph (1) p. 435, of tile fails to meet the requirements of the absorption test, the manufacturer or other seller may demand recourse to the freezing and thawing test, to be made at his expense. In such recourse, the number of tiles tested shall be four times the number represented by the standard sample, paragraph (1) p. 435. If the material passes the freezing and thawing test satisfactorily, it shall not be rejected on account of its failure to meet the absorption requirements specified in Table I, but the average percentage of absorption of the specimens used in the freezing and thawing test shall be adopted as the maximum allowable mean absorption for the contract in question.

TABLE I

PHYSICAL TEST REQUIREMENTS FOR DIFFERENT CLASSES OF DRAIN TILE

CAUTION.—Drain tile meeting these requirements are not necessarily safe against cracking in ditches. For safe requirements as against cracking, see Table II.

Internal Diameter of Tile, in.	Farm Drain Tile				Standard Drain Tile				Extra-Quality Drain Tile			
	Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent		
		Shale and Fire-Clay Tile	Surface-Clay Tile	Concrete Tile		Shale and Fire-Clay Tile	Surface-Clay Tile	Concrete Tile		Shale and Fire-Clay Tile	Surface-Clay Tile	Concrete Tile
4	800	11	14	12	1200	9	13	10	1600	7	11	9
5	800	11	14	12	1200	9	13	10	1600	7	11	9
6	800	11	14	12	1200	9	13	10	1600	7	11	9
8	800	11	14	12	1200	9	13	10	1600	7	11	9
10	800	11	14	12	1200	9	13	10	1600	7	11	9
12	800	11	14	12	1200	9	13	10	1600	7	11	9
15	1000	11	14	12	1300	9	13	10	1600	7	11	9
18					1400	9	13	10	1800	7	11	9
21					1550	9	13	10	2100	7	11	9
24					1700	9	13	10	2400	7	11	9
27					1850	9	13	10	2700	7	11	9
30					2000	9	13	10	3000	7	11	9
33					2150	9	13	10	3300	7	11	9
36					2300	9	13	10	3600	7	11	9
39					2450	9	13	10	3900	7	11	9
42[a]	(Not permitted)	(Not permitted)	(Not permitted)	(Not permitted)	2600	9	13	10	4200	7	11	9

[a] Larger sizes recommended as standard are as follows: 45, 48, 54, and 60 in.

(4) In the strength tests, individual tiles of a standard test whose mean strength is satisfactory may fall 25% below the requirement for the average without causing rejection. In the absorption test, the absorption of individual tiles of a standard sample, paragraph (1) p. 435,

NOTE—When the freezing and thawing test is made as provided in paragraph (D1) p. 431, the number of freezings and thawings to be endured shall be as follows: For farm drain tile, 24; for standard drain tile, 36; for extra-quality drain tile, 48.

TABLE II
STANDARD ORDINARY SUPPORTING STRENGTHS OF DRAIN TILE FOR ORDINARY SAND AND FOR THOROUGHLY WET CLAY DITCH FILLING MATERIALS
(Strengths in Pounds per Linear Foot)

Height of Fill above Top of Tile, ft.	Breadth of Ditch at Top of Tile																			
	1 ft.				2 ft.				3 ft.				4 ft.				5 ft.			
	Method of Laying Pipe				Method of Laying Pipe				Method of Laying Pipe				Method of Laying Pipe				Method of Laying Pipe			
	Ordinary		First Class		Ordinary		First Class		Ordinary		First Class		Ordinary		First Class		Ordinary		First Class	
	Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material		Ditch Filling Material	
	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay	Sand	Clay
2	265	280	220	235	615	635	510	530	970	990	810	830	1 330	1 350	1 110	1 130	1 690	1 710	1 410	1 430
4	400	450	335	375	1 050	1 120	880	935	1 750	1 820	1 460	1 520	2 450	2 540	2 040	2 110	3 160	3 250	2 640	2 710
6	470	545	390	455	1 370	1 500	1 140	1 250	1 370	2 530	1 980	2 110	3 410	3 580	2 840	2 980	4 460	4 640	3 720	3 870
8	505	605	420	505	1 600	1 790	1 330	1 490	2 870	3 110	2 390	2 590	4 220	4 490	3 510	3 740	5 590	5 890	4 660	4 910
10	525	640	440	535	1 760	2 010	1 470	1 680	3 270	3 610	2 730	3 010	4 900	5 290	4 080	4 410	6 590	7 020	5 490	5 850
12	535	660	445	550	1 880	2 190	1 570	1 820	3 600	4 030	3 000	3 355	5 480	6 000	4 570	5 000	7 460	8 030	6 220	6 690
14	540	675	450	560	1 960	2 320	1 640	1 930	3 850	4 380	3 210	3 650	5 980	6 620	4 980	5 520	8 230	8 950	6 850	7 460
16	545	680	455	565	2 030	2 420	1 690	2 020	4 060	4 670	3 390	3 890	6 400	7 160	5 330	5 970	8 890	9 770	7 410	8 150
18	545	685	455	570	2 070	2 500	1 720	2 090	4 230	4 920	3 530	4 100	6 750	7 630	5 630	6 360	9 480	10 520	7 900	8 770
20	545	690	455	575	2 100	2 560	1 750	2 140	4 370	5 130	3 640	4 280	7 050	8 060	5 880	6 720	9 990	11 200	8 330	9 330
22	545	690	455	575	2 120	2 610	1 770	2 180	4 470	5 310	3 730	4 420	7 310	8 430	6 090	7 020	10 400	11 800	8 700	9 830
24	545	690	455	575	2 140	2 650	1 780	2 210	4 560	5 450	3 800	4 540	7 520	8 750	6 270	7 290	10 800	12 300	9 030	10 300
26	545	690	455	575	2 150	2 670	1 790	2 230	4 630	5 580	3 850	4 640	7 700	9 030	6 420	7 530	11 200	12 800	9 320	10 700
28	545	690	455	575	2 160	2 700	1 800	2 250	4 680	5 680	3 900	4 740	7 860	9 280	6 550	7 740	11 500	13 300	9 570	11 100
30	545	690	455	575	2 170	2 710	1 810	2 260	4 730	5 770	3 940	4 810	7 990	9 500	6 660	7 920	11 800	13 700	9 800	11 400
Very great	545	690	455	575	2 180	2 770	1 820	2 310	4 910	6 230	4 090	5 190	8 730	11 100	7 260	9 230	13 600	17 300	11 400	14 400

NOTE: Ordinary Pipe Laying is pipe laying in accordance with customary good practice in tile-drain construction, whereby the underside of the pipe is well bedded on soil for 60 to 90° of the circumference.

First-Class Pipe Laying is pipe laying in accordance with the best customary practice in pipe-sewer construction, whereby the entire underside of the pipe is very thoroughly bedded on soil and the entire pipe is surrounded by well-compacted soil, under the direction of an inspector constantly present on the work.

When pipe is laid in a Concrete or Other Permanent Masonry Cradle, strong enough to carry the entire load to the sub-base without breaking and large enough to prevent material settlement, the standard strengths for all dimensions of ditches and all filling materials shall be those specified for Standard Drain Tile in Table I.

which gives a satisfactory mean absorption percentage, may exceed the average by 25% without causing rejection. In the freezing and thawing test, at least 95% of all the tile tested shall meet the requirement.

In the event of the failure of a standard sample (paragraphs (D3), p. 432 and (1), p. 435) to meet the above requirements, the manufacturer or other seller may thoroughly cull the material and submit a portion for retest at his own expense, and for such retest the number of tiles per sample shall be 10 for the strength and absorption tests and 20 for the freezing and thawing test. In the event of the failure of the material after culling to pass the requirements it shall be rejected without further test.

(5) The manufacturer or other seller shall not be held responsible for cracking of drain tile in ditches unless by special agreement in advance, and in any event his obligation shall be held to be discharged by the delivery of drain tile having the minimum of ordinary supporting strengths specified in Table II; and if it is not otherwise specified in advance by the purchaser, tile shall be supplied of the strengths specified for clay ditch filling, for "ordinary" pipe laying and for widths of ditch at the level of the top of the tile equal to 0.5 ft. greater than the outside diameters of the tile. The purchaser shall furnish to the manufacturer or other seller complete information, in advance of receiving bids, as to the number of linear feet of drain tile of each diameter required for each different depth of ditch, measured to the nearest foot from the surface of the ground to the top of the tile.

(F) Visual Inspection

(1) All drain tile shall be given a thorough visual inspection at the trench by a competent inspector employed by the purchaser. The purposes of the visual inspection shall be (1) to cull and reject imperfect individual tiles, and (2) to determine whether the tile, independently of meeting the chemical and the physical test requirements, comply with the specifications of general properties, especially as stated hereinafter.

(2) All drain tile shall be of approximately circular cross-section, except when otherwise specified in advance. They shall be approximately straight, except in the case of special connections. The ends shall be so regular and smooth as readily to admit of making close joints by turning and pressing together adjoining tile.

(3) The sizes of drain tile shall be designated by their interior diameters.

(4) Drain tile smaller than 12 in. in diameter shall have a minimum length of 12 in. Tile of from 12 to 30 in. in diameter, inclusive, shall

have lengths not less than the diameters. Tile larger than 30 in. in diameter shall have a minimum length of 30 in.

(5) Drain tile shall be substantially uniform in structure throughout, and the inspector shall investigate this property by examining fractured surfaces.

(6) Drain tile shall give a clear ring when stood on end and while dry tapped with a light hammer.

(7) The inspector may use the color of drain tile as a general guide in sorting and inspecting, but he shall first so familiarize himself with the raw materials and the processes used in the manufacture of the particular tile in question as to be competent to interpret the true meaning of variations in their color.

(8) Drain tile shall be reasonably smooth on the inside.

(9) Drain tile shall be free from cracks and checks extending into the body of the tile in such a manner as to decrease the strength appreciably. Tile shall not be chipped or broken in such a manner as to decrease their strength materially or to admit earth into the drain.

(10) All drain tile shall be sufficiently "vitrified" or "hard-fired" to afford the degree of supporting strength, percentage of absorption, and resistance to freezing and thawing specified in the physical test requirements prescribed in Table I.

(11) The manufacturer or other seller may appeal from decisions of the inspector on questions of strength or structure when such decisions are based on visual inspection alone, in which case the point at issue shall be determined by standard physical tests, the cost of which shall be paid by the appellant if the inspector was right, or by the purchaser if his inspector was in error.

TABLE III

DISTINCTIVE GENERAL PHYSICAL PROPERTIES OF DIFFERENT CLASSES OF DRAIN TILE

Physical Properties Specified	Farm Drain Tile	Standard Drain Tile	Extra-Quality Drain Tile
Allowable variation of average diameter below specified diameter, per cent	5	3	3
Allowable variation between maximum and minimum diameters of same tile, or average diameters of adjoining tile, percentage of thickness of wall	85	75	65
Allowable variation from straightness, percentage of length	5	3	3
Allowable thickness of exterior blisters, lumps and flakes which do not weaken tile and are few in number, percentage of thickness of wall	25	20	15
Allowable diameters of above blisters, lumps and flakes, percentage of internal diameter	20	15	10
General inspection	Careful	Rigid	Very rigid

(12) Drain tile of the different classes shall in addition to all requirements heretofore specified, have the distinctive physical characteristics prescribed in Table III.

(G) Testing, Inspection, and Rejection

(1) All tests shall be made by experts employed by the purchaser. Full reports of all tests shall be furnished the manufacturer or other seller on his request. Tests shall be made and reported promptly.

(2) The purchaser shall pay the expense of making all tests except as otherwise specified in paragraphs (3) p. 432, (3) p. 437, (11) p. 440, and (4) below.

(3) The number of standard rests to be made shall be determined by the purchaser.

(4) In all contracts for ten or more carloads of tile, preliminary general tests and inspection shall be made at the factory by the purchaser upon demand of the manufacturer or other seller. The expense of such tests and inspection shall be paid by the manufacturer or other seller.

(5) The inspector shall be employed by the purchaser.

(6) The manufacturer or other seller of the drain tile shall afford the inspector all reasonable facilities for his work, both as to the selection of specimens for tests, and as to visual inspection. Inspection shall be completed promptly.

(7) The inspector shall plainly mark all drain tile which he rejects, and such rejected tile shall be removed promptly by the manufacturer or other seller. Upon request of the purchaser, the manufacturer or other seller shall give full account of the removal of rejected tile.

VII. SAMPLING CERAMIC MATERIALS

43. STANDARD METHOD FOR SAMPLING CERAMIC MATERIALS AS DELIVERED[1]

(A) Shipped and Stored in an Unground Condition

"Unground condition" shall mean material as mined which has not been crushed, ground, or intentionally mixed.

(1) Time of Sampling The material shall be sampled when it is being placed into or taken from railroad cars, ships, barges, wagons, casks, bags, etc. Samples can usually be taken advantageously as the material passes through the crusher. Samples collected from the surface of piles, bins, cars, etc., are generally unreliable. If it is necessary, however, to sample under such conditions, one-half the sample shall be taken from the lower third and one-half from the upper two-thirds.

(2) Collection of the Gross Sample To collect samples, a shovel or specially designed tool or mechanical means shall be used for taking equal portions or increments. The increments shall be regularly and systematically collected so that the entire quantity of material sampled will be represented proportionately in the gross sample, and with such frequency that the gross sample of the required amount shall be collected.

(3) Size The standard gross sample shall not be less than 1% of the total shipment.

(B) Shipped and Stored in a Crushed or Pulverized Condition

(1) Time of Sampling If the material is shipped loose, the sampling shall be done during loading or unloading as described under Section 43 (A1).

If the material is in containers, all containers of each shipment shall be so marked, tagged, or labeled that they can be distinguished from all other shipments, and that ready reference can be had to the shipper's name and the date of delivery.

(2) Method of Collection If the material is loose the gross sample shall be taken as described under paragraph (2) above. If in containers, an opening shall be made in the sack or barrel and a portion of the contents shall be withdrawn. This sample should not be taken from the top alone but should represent all portions of the contained material. This can be done with the aid of an open pipe, spoon-shaped rod, or other suitable apparatus. If there is any

[1] Adopted 1922.

reason to doubt the uniformity of the shipment, it is best to test separately a larger sample from each container.

(3) Size The standard gross sample shall not be less than 0.2% of the total lot sampled.

(C) Treatment of the Gross Sample

(1) Crushing After the gross sample has been collected in the case of unground material, it shall be systematically crushed, mixed, and reduced in quantity by quartering to convenient size for testing. The largest sizes of pieces allowable with various weights of samples are shown in the following table.

100 lbs.+	2.0 in.
100–50 "	1.0 in.
50–25 "	0.25 in.
25–10 "	No. 4-sieve
10–5 "	No. 10-sieve
5 "	No. 20-sieve

(2) Quartering The sample crushed to the required size shall be thoroughly mixed by coning and re-coning on a clean surface. The cone shall be flattened and then marked into quarters by two lines which intersect at right angles directly under a point corresponding to the apex of the original cone. The diagonally opposite quarters shall then be removed and the space that they occupied brushed clean. The material remaining shall be successively crushed, mixed, coned, and quartered until two opposite corners shall equal the size necessary for testing.

The final portion shall be placed in a container suitable for storage or shipment and carefully marked.

References

G. S. Pope, "Methods of Sampling Delivered Coal," U. S. Bur. Mines, *Bull.*, No. 116.

"Report of Sub-Committe on Field Sampling of Clays," Comm. on Ceramic Chemistry of National Research Council.

H. F. Staley and M. F. Beecher, "Practical Handling of Iowa Clays," Iowa Eng. Expt. Sta., *Bull.*, No. 43.

44. TENTATIVE METHOD FOR SAMPLING CLAY DEPOSITS

(1) Preliminary Sampling A face of the body of clay to be sampled shall be carefully stripped of loose or foreign materials, and a series of parallel trenches cut, each a straight line, so as to make as nearly as may be a vertical section entirely across the outcrop. In the case of stratified or bedded deposits which are inclined, the direction of these trenches shall be, preferably, across the dip, so that a proportionate amount of clay will be obtained from each indi-

vidual layer. Each trench shall be about 12 inches wide, and deep enough to produce at least 100 pounds of material. Where natural outcrops are not available for a sampling, preliminary trials may be made with a hand auger, and test pits dug to the necessary depth to expose a section (or face) of the clay.

As this may yield more material than is necessary for even a complete series of tests, the clay from the different trenches shall be reduced to lumps not exceeding 2 inches in diameter, mixed together and reduced by quartering to about 100 pounds which is to be sent to the testing laboratory. The quartering shall be done on a heavy sail cloth at least 8 feet square.

If the deposit shows distinct difference in regard to structure, color, or texture, each bed showing these individual differences shall be sampled separately, provided they are sufficiently thick to be mined by themselves or can be thrown out if undesirable.

Where the clay is stored in stock piles the sample may be taken from these, *provided they are representative.* At least one-half of the sample shall be taken from the lower third of the pile.

In the case of those clays which are being purified a sample of both the crude material and the clay as prepared for the market shall be taken.

The samples collected as outlined above shall be placed in clean tight-weave strong sacks and carefully labeled by means of two tags each bearing the proper identification marks. One folded tag shall be placed within the sack and the other securely attached to the outside.

(2) Extended Sampling After a clay proves satisfactory in the preliminary testing, the surrounding tract must be surveyed and systematically sampled. A topographical survey of the tract shall be made. Holes shall be drilled or dug through the deposit not more than 100 feet apart. A record shall be kept of the thickness of each stratum encountered. By plotting these results to scale the shape, size, and dip of the strata can be estimated.

A few larger holes may be dug at the extremities of the property or at any points of doubtful value in order to get samples large enough for a complete series of tests. These should be taken under the direction of "Preliminary Sampling."

VIII. PREPARATION OF CLAY TRIALS

45. FORMING CLAY TRIALS

(1) Size and Shape of Test Piece The test piece is made 30 by 30 by 45 mm. ($1^1/_8$ by $1^1/_8$ by $1^7/_8$ inches) for a definite reason. It is about as large as it can be made and have a plastic volume less than 50 cc. If the volume is greater than 50 cc. it necessitates the use of larger burettes, which are cumbersome and more easily broken. It is also a convenient size for handling in placing in a volumeter as well as placing in the kiln for draw trial firing. If any longer, the total number that could be placed in the kiln would be cut down. If any larger in cross-section they would be inconvenient in handling in the kiln, particularly if tongs were used.

(2) Making Test Pieces Figure 1 shows a metal mold suitable for use in forming the test pieces. The length may be altered but it has been found that it is preferable to make the bars as long as possible and then to cut them into pieces of the proper length for test. This method gives a more uniform structure through the entire cross-section.

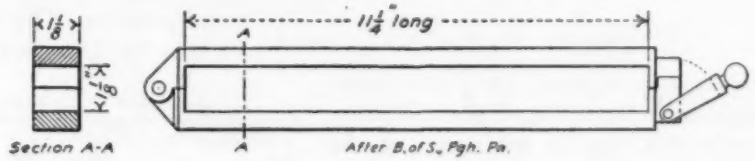


FIG. 1.

The cutting may be facilitated by having a small miter box into which the plastic clay bar is placed, always keeping it on the small pallet on which it was made, and cutting it into the proper length with a fine steel wire stretched on a suitable frame. It is also advantageous to pick the soft test pieces up without injuring them. This can be done very well by using thin strips of wood or metal the length of the test piece and as wide as the test piece is high. Use one on each side of the piece and press them gently until the piece can be lifted between them.

46. FORMING AND HANDLING CLAY TEST PIECES

(Process of E. E. Pressler (Abbreviated))

(A) Preparation of Plastic Clay Body The plastic clay body is prepared from the 20-mesh air-dry material by mixing with it the required water of plasticity, and passing twice through a small pug mill. About 500 grams of the air-dry clay are required for

each series of four trial bars to be prepared, and five series of four bars are required for the regular testing procedure. The pugged clay is transferred to the pounding box (Fig. 2), and consolidated by pounding with the pounding maul (Fig. 3). The clay is introduced into the box in small portions at a time and distributed uniformly over the bottom, and each portion compacted before more is added. Care is observed to avoid causing striae or other texture irregularities by unequalized application of pressure. The bottom of the box is finally removed, and the clay mass pressed into the mold of the trial cutting templet (Fig. 4) by means of the maul.

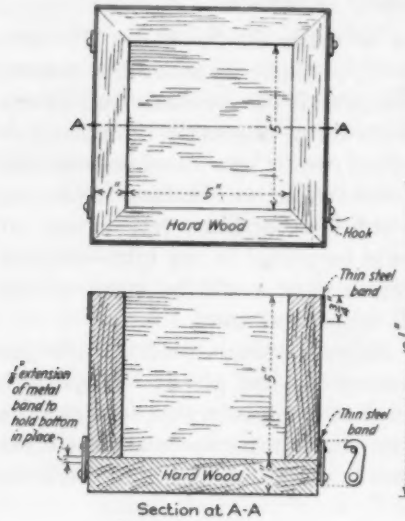


FIG. 2.

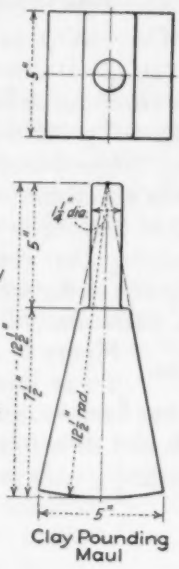
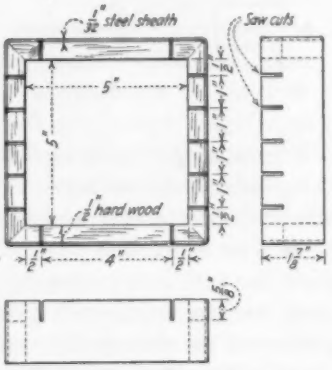


FIG. 3.

(B) Preparation of Trial Bars

(1) Method of Cutting Bars The mold is prepared to receive the compacted clay by oiling with a kerosene-saturated cloth, and stretching a sheet of tissue paper over the bottom board. The clay mass is pressed firmly into the mold with the maul. The clay surface is trimmed to the level of the sides of the mold by means of a cutting wire, and smoothed with the blade of a 6-inch spatula. The trials are then expelled by means of a false bottom-board under the mold. Cut with a wire in saw cuts and place identifying numbers on each trial bar.



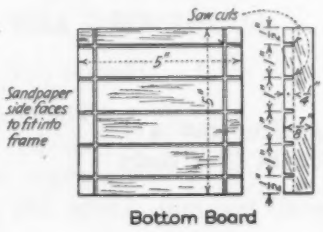


FIG. 4.

(2) Method of Drying Trial Bars

The plastic bars are placed upon a flat surface, and carefully transferred to a cord drying support which is made by stretching cords at $^1/_8$-inch intervals over a rectangular frame. A suitable drying atmosphere must be provided, for which purpose a covering of cheese cloth may be used, if found desirable. The trials should be left on the cord support until all danger of warpage in drying is past. When well air dry, the bars are dried at 110°C for five hours, and set aside in a dessicator containing calcium chloride for further tests.

IX. STANDARD TEST METHODS

47. STANDARD METHOD FOR SLAKING TEST

(A) Preface

The method here defined differs but little from the practice which is generally followed. The principal amendments are in the closer specifications on the size of screen and temperature of water. The latter particularly has a marked effect upon the slaking values obtained.

(B) Method

(1) Test Pieces The test pieces shall be cubes made of a mixture of 50% by weight of ground flint, and 50% of the clay to be tested which has been ground to pass a No. 30 sieve. (Tentative Standard Series of Testing Sieves). The flint shall be of the grade and fineness ordinarily termed "potters' flint" and shall all pass a No. 100 sieve (Tentative Standard Series of Testing Sieves). The cubes shall be 2.5 cm. (1 inch) on an edge in the wet state.

(2) Making the Test Pieces The test pieces shall be made by pugging or working the mixture by hand to its best plastic consistency, batting out into a slab 2.5 cm. (1 inch) thick, cutting from this a strip 2.5 cm. (1 inch) wide and subdividing this strip into 2.5 cm. (1-inch cubes).

(3) Drying The drying shall be accomplished in three stages, (*a*) at room temperature until air dry, (*b*) at a temperature between 64°C and 76°C for at least five hours, and finally (*c*) without allowing to cool to room temperature at 110°C until approximately constant in weight. The test pieces shall then be cooled to room temperature in a desiccator.

(4) The Screen The slaking shall be done on screens corresponding to a No. $2^1/_2$ sieve (Tentative Standard Series of Testing Sieves).

(5) Water The temperature of the water shall be held at 25°C ± 1°C, or 77°F ± 2°F.

(6) Slaking After the samples are thoroughly dried and cooled paragraph (1) above, they shall be placed on a screen and carefully immersed in water, care being taken to prevent agitation of the water during the slaking operation. The water shall be at least 2.5 cm. (1 inch) deep under the test piece and the top of the piece shall be immersed in the water to a depth of not less than 1.2 cm. ($^1/_2$ inch) and not more than 2.5 cm. (1 inch).

(7) Report The only datum to be obtained is the time required in minutes for the whole of the test piece to slake and settle through the screen. The time reported shall be the average of two determinations.

48. STANDARD METHOD FOR WATER OF PLASTICITY[1]

(1) Test Pieces The test pieces shall be of the same size and shape and made in the same manner as defined in the Method for Drying Shrinkage, Section 50 (1), (2), and (3), p. 450.

(2) Plastic Weight The edges and corners of three test pieces shall be rubbed lightly with the finger to prevent loss in handling. They shall then be weighed on a balance to an accuracy of 0.1 gram.

(3) Drying After the plastic weight is obtained the test pieces shall be allowed to dry at room temperature until air dry. They shall then be dried at between 64°C and 76°C for at least five hours and finally at 110°C until approximately constant in weight.

(4) Dry Weight The dried test pieces shall be cooled to room temperature in a desiccator and then weighed with the same accuracy as before (paragraph (2)).

(5) Calculation The water of plasticity shall be calculated as a percentage of the weight of the dry clay bar, by the following formula:

$$T=\frac{Wp-Wd}{Wd}\times 100$$

in which T = per cent water of plasticity
Wp = weight of the plastic test piece
Wd = weight of the dry test piece

(6) Report The average of the three values obtained shall be reported as the per cent water of plasticity.

49. STANDARD METHOD FOR SHRINKAGE AND PORE WATER

(A) Preface

"Shrinkage water" is defined as that portion of the water of plasticity which is driven off up to the point where shrinkage ceases. "Pore water" is defined as that portion of the water of plasticity which is is driven off from the point where shrinkage ceases until the clay piece has reached approximately constant weight at 110°C. Thus shrinkage water plus pore water equals the water of plasticity.

[1] Adopted 1920.

(B) Method

(1) Data The data necessary for the calculations here involved are the plastic volume and the dry volume, as determined in the Method for Drying Shrinkage, and the dry weight and water of plasticity as determined in the Method for Water of Plasticity.

(2) Shrinkage Water The following formula shall be used:

$$t_1 = \frac{Vp - Vd}{Wd} \times 100$$

in which t_1 = the per cent shrinkage water
Vp = the plastic volume in cubic centimeters
Vd = the dry volume in cubic centimeters
Wd = the dry weight in grams

(3) Pore Water The following formula shall be used:

$$t_2 = T - t_1$$

in which t_2 = the per cent pore water
T = the per cent water of plasticity

50. STANDARD METHOD FOR DRYING SHRINKAGE[1]

(1) Size and Shape The test pieces shall be made approximately 30 by 30 by 45 mm. ($1^1/_8$ x $1^1/_8$ x $1^7/_8$ inches). It is apparent that the dry dimensions will vary with different clays.

(2) Preparation The clay shall be thoroughly dried at a temperature above 64°C but under 76°C and crushed to pass a standard No. 20-sieve. (Tentative Standard Scales for Testing Sieves.) It shall then be made up with water to a soft plastic consistency and thoroughly wedged and kneaded by hand.[2]

(3) Making Test Pieces The test pieces shall be made in a suitable metal mold[3] measuring approximately 30 by 30 mm. ($1^1/_8$ x $1^1/_8$ inches) by any desired length. After making, the pieces shall be cut into 45 mm. ($1^7/_8$ inch) lengths. The mold shall be thinly and evenly oiled with kerosene or a light machine oil only as frequently as is necessary to keep the clay from sticking. The test piece shall be formed by taking in the hand a lump of clay, somewhat larger than required to fill the mold, and kneading it into a roll approximately the length of the mold. It shall then be placed in the mold and forced into the corners by blows with the cheek of the fist. The excess shall then be struck off with a wire and the piece slicked with a spatula and appropriately marked or numbered for indentification. Care should be

[1] Adopted 1920.

[2] This consistency will permit of the careful handling of the piece immediately after forming.

[3] See Appendix for detail of suitable molds.

taken by the operator to keep his hands free from oil. The test piece shall be removed from the mold immediately and transferred to a smooth, straight pallet, care being taken not to distort it.

If preferred, the test piece may be made in a piston plunger press fitted with a die 30 mm. ($1^1/_8$ inches) square. In either event the corners of the test piece shall be slightly rounded.

(4) Plastic Volume The plastic volume shall be determined immediately in a volumeter of the Seger type.[1] Kerosene with a specific gravity of about 0.8 shall be used as the measuring fluid. The volume shall be read to the nearest 0.1cc.

(5) Drying After the plastic volume is determined the surfaces of the test pieces shall be dried lightly with a soft cloth to remove the film of kerosene, and allowed to dry at room temperature until air dry. They shall then be dried at a temperature between 64°C and 76°C for at least five hours and finally at 110°C to approximately constant weight. They shall not be allowed to cool to room temperature between these two drying operations unless they be placed in a desiccator. After the final drying treatment they shall be placed in a desiccator to cool and remain there until the test is continued.

(6) Dry Volume The dry test pieces shall then be allowed to soak in kerosene of the same specific gravity as that used in the volumeter for at least 12 hours, after which the volume shall be determined in the same manner as specified for the plastic volume in paragraph (4). The volume shrinkage shall be calculated by the following formula:

$$b = \frac{Vp - Vd}{Vd} \times 100$$

in which b = per cent volume shrinkage
Vp = the plastic volume
Vd = the dry volume

(7) Linear Shrinkage This value shall be calculated from the per cent volume shrinkage by the formula:

$$a = 100\left[\sqrt[3]{1 + \frac{b}{100}} - 1\right]$$

in which a = per cent linear shrinkage

(8) Report In reporting drying shrinkage, the following information shall be given and these values shall be the means of results obtained on two test pieces: (*a*) volume shrinkage in percentage of the dry volume, and (*b*) linear shrinkage in percentage of the dry length.

[1] For details of several instruments see Appendix.

51. STANDARD METHOD OF TESTING FOR PYROMETRIC CONE EQUIVALENT (P.C.E.)

This method is applicable to fire brick and refractory materials in general, as well as to clays.

(1) Preparation The sample shall be obtained with the same care and precision as for chemical analysis. If the material is hard enough to require it, it may be reduced in a hardened tool-steel mortar using a pestle of the same sort, to a fineness allowing of finish grinding in an agate mortar. After grinding in the steel mortar, in the case of fired samples, any iron introduced by the mortar must be removed with a magnet before grinding is finished.

The sample shall be finally ground to pass a No. 60 sieve (Tentative Standard Scale for Testing Sieves), care being taken to prevent excessive reduction of the fines, by frequent removal through the sieve.

(2) Test Pieces The test pieces shall be the size and shape of pyrometric cones; tetrahedra 7 mm. along the edge of the base and 30 mm. high. They shall be molded in steel molds, preferably allowing a somewhat greater height so that they may be cut to the required dimension when dry. If the sample is of a fired material or one deficient in plasticity, an organic binder such as gum or glue may be added to facilitate molding. If desired, the test pieces may be biscuited at a temperature safely below vitrification before mounting.

(3) Mounting The test pieces shall be mounted on a plaque of refractory material of such a composition as will not affect their fusibility; *e.g.*, equal parts of a highly refractory clay and fused alumina passing a No. 100 sieve. The base of the test pieces and pyrometric cones shall be imbedded not more than 2 mm. in the plaque, and their troweled faces (the numbered face of the pyrometric cones) shall make an angle of 82° with the plaque.

The test pieces shall be arranged on the plaque, alternating with pyrometric cones of successive numbers.

The pyrometric cones here specified shall be of the Seger formulas as manufactured by Edward Orton, Jr.

The plaque may be of any convenient size and shape and may be biscuited, if desired, after mounting cones and test pieces, at a temperature safely below the vitrification of the test pieces.

(4) Furnace The furnace shall preferably be one which will give a neutral or oxidizing atmosphere, and the heating chamber shall be frequently explored to discover any unequal heating. In a gas or oil furnace, care shall be taken that the flame does not impinge directly upon the test pieces, cones, or plaque. Excessive reducing conditions should be avoided.

(5) Rate of Heating The heating shall be carried out in a suitable furnace at a rate to conform to the following requirements:

Time Interval	Minutes
To reach cone 20	45
To cone 23	20
" " 26	6
" " 27	4
" " 28	4
" " 29	10
" " 30	4
" " 31	8
" " 32	4
" " 33	8
" " 34	18
" " 35	6

NOTE: At 1000°C the old cone pat may be removed and a new one put in without cooling the furnace down below red heat.

(6) Softening Point or Pyrometric Cone Equivalent The pyrometric cone equivalent of a cone or test piece is indicated by its tip bending over and touching the plaque. The softening point of the test piece shall be reported in terms of the serial number of the pyrometric cone which corresponds in time of softening with the test piece. If the test cone softens later than one standard cone and earlier than the next, the pyrometric cone equivalent shall be reported thus: cone 31–32.

If the test piece starts bending at an early cone but is not down until two or more successive higher cones have softened, the fact shall be reported; also any bloating, squatting, or unequal fusion of constituent particles.

Two or more tests at the proper temperature shall be made.

52. STANDARD METHOD FOR TRUE SPECIFIC GRAVITY

(1) Sample For raw ceramic materials the sample shall be taken with the same care and precision as for chemical analysis. For fired materials the sample shall consist of at least two portions of the test piece or ware, from different positions, and the ratio of original surface to volume shall not be greater than in the whole piece.

The sample shall be crushed between hardened steel surfaces, when crushing is necessary, and then ground in an agate mortar, to pass a No. 100 sieve (Tentative Standard Scale for Testing Sieves). In fired samples or those not likely to contain magnetic material as an original constituent, any magnetic material present after crushing shall be removed with a magnet. About 10 grams shall be prepared in this manner, dried to constant weight at 110°C, and placed in a glass-stoppered weighing bottle.

(2) The Pycnometer The pycnometer shall be of good quality and workmanship with the mouth ground flat so that there shall be no rounded recess between stopper and bottle when the stopper is in place. The stopper with a capillary tube shall be used.

(3) Weighing All weighings shall be made on an accurate chemical balance to the third decimal place in grams, with material, and in an atmosphere at a temperature of 20°C ± 1°C. The weight of the bottle and stopper dried at 110°C shall be recorded as p and the weight of the bottle filled with distilled water with the stopper in place as w_1.

(4) Introducing the Sample About two grams of the sample shall be placed in the pycnometer (which has been dried at 110°C) and weighed with the stopper, the weight being recorded as w. The bottle shall then be filled to approximately one-third its capacity with distilled water, the stopper put in place with a piece of paper between stopper and bottle to prevent sticking, and boiled with care for 15 minutes. The bottle shall then be filled with distilled water to the base of the neck and allowed to cool to 20°C ± 1°C. When cool and the sample settled, the filling shall be completed and the bottle wiped dry with a soft cloth.

(5) Final Weighing The pycnometer shall then be weighed and the weight recorded as w_2.

(6) Calculation The true specific gravity shall be obtained by the formula:

$$Gl = \frac{w - p}{(w - p) - (w_2 - w_1)}$$

in which Gl = the true specific gravity
w = weight of the stoppered pycnometer and sample
p = weight of the stoppered pycnometer
w_1 = weight of the stoppered pycnometer filled with water
w_2 = weight of the stoppered pycnometer sample and water

(7) Checks Two determinations shall be made and reported and they shall check to within 0.005.

53. STANDARD METHOD FOR BEHAVIOR IN FIRING[1]

(A) Preface

Data Required In order to determine the behavior of a clay in firing, the following data must be obtained: (*a*) progressive change in porosity, and (*b*) progressive change in volume.

[1] Adopted 1920.

Additional Useful Data Knowledge of the following properties will always be useful, checking, in a measure, the accuracy of the above determinations: changes in (*c*) color, (*d*) hardness, (*e*) absorption, (*f*) mechanical strength, and (*g*) apparent specific gravity.

(B) Method

(1) Test Pieces The clay shall be prepared and the test pieces formed, as defined in the Method for Drying Shrinkage, Section 50 (1) (2) (3), p. 450. They shall then be dried and the dry volume determined as defined in (5 and 6) p. 451 of the same Method.

(2) Firing The test pieces shall be placed in a refractory muffle or sagger as thin-walled as possible, which is set in the test kiln. The test pieces shall not be stacked together too compactly. The test kiln shall be of such size that the effective space available is not less than $1^1/_2$ cubic feet. The heating may be accomplished by any convenient means but the temperature distribution should be thoroughly explored during the first few firings. A set of pyrometric cones of the Seger formulas as made by Edward Orton, Jr., shall be placed as closely to the stacked-up test pieces as possible;[1] but temperature control by means of a platinum platinum-rhodium thermocouple is required also. The temperature therefore shall be reported in terms of cones and the pyrometric readings, in which correction has been made for the cold junction temperature.

The range of cones used shall cover the firing range of the clay, which must be judged by the operator. Generally, the cones to be placed in the kiln are 014 to 3 for impure, common brick clays; $012^1/_2$ to 5 for shales and the better types of ferruginous clay; and 02 to 15 for clays of the fireclay type. Oxidizing conditions must be maintained during firing.

The heating shall preferably be at the rate of 45°C per hour from the start of the firing until a heat treatment is reached, corresponding to the softening point of the third consecutive cone below that at which the first trial is to be drawn; and 20°C per hour from that point until the end of the firing. In no case shall the rate of heating be greater than 60°C per hour or less than 30°C per hour for the first period, or greater than 25°C per hour or less than 15°C per hour for the last period.

(3) Drawing the Test Pieces According to the nature of the clay, test pieces are first drawn at cone 010 for impure, common brick clays; cone 08 for shales and the better grades of ferruginous clay; cone 2 for clays of the fireclay type. A test piece

[1] A suitable arrangement of cones and test pieces is illustrated in the Appendix.

is then drawn from the kiln at each interval of two cones, and immediately before drawing the temperature indicated by the pyrometer shall be recorded. The removal of the test piece from the kiln shall be done as quickly as possible to avoid cooling down the kiln too much. It will be necessary as a rule to increase the rate of application of heat a little after each draw.

Upon removal from the test kiln the test pieces shall be (*a*) immediately covered with hot sand or (*b*) placed in a small supplementary furnace kept at a dark red heat and large enough to hold all of the test pieces to be drawn. Upon completion of the firing the auxiliary furnace shall be allowed to cool at the natural rate. (While it is recognized that furnace control by means of a thermocouple is more definite and accurate than with pyrometric cones, especially for testing purposes, trials have demonstrated that the use of cones minimizes the variations between one firing and another due to slight differences in rate and uniformity of heating.)

(4) Weighing When cool enough to handle, the test pieces shall be placed in a desiccator containing concentrated sulphuric acid until they have cooled to room temperature. They shall then be carefully inspected and any adhering particles of sand or other material, picked up during firing, carefully removed. They shall then be weighed on a balance to an accuracy of 0.1 gram.

(5) Saturation The weighed test pieces shall be placed in distilled water in a suitable vessel and boiled for two hours, then allowed to cool to room temperature, while still immersed in water. During boiling, the test pieces shall not be in contact with the heated bottom of the container.

(6) Saturated Weight When cooled to as near 20°C as possible in the room atmosphere, each test piece shall be dried lightly with a damp towel to remove the excess water and weighed in air to an accuracy of 0.1 gram.

(7) Fired Volume The fired volume shall be determined in a volumeter of approved type.[1]

54. APPARENT POROSITY

The apparent porosity[2] shall be calculated by means of the following formula:

$$P=\frac{Sf-Wf}{Vf}\times 100$$

[1] For details of several instruments see Appendix.

[2] For refined method for special bodies see Appendix.

in which P = the per cent apparent porosity
Sf = weight of the saturated fired test piece in grams
Wf = weight of the fired test piece in grams
Vf = volume of the fired test piece in cubic centimeters.

55. VOLUME CHANGE

The volume change shall be determined by the relation

$$b_1 = \frac{Vd - Vf}{Vd} \times 100$$

in which b_1 = per cent volume change
Vd = volume of the dry test piece in cubic centimeters.

56. APPARENT SPECIFIC GRAVITY[1]

The apparent specific gravity shall be determined by the formula

$$G = \frac{Wf}{Vf - (Sf - Wf)}$$

in which G = the apparent specific gravity.

57. BULK SPECIFIC GRAVITY

The bulk specific gravity shall be calculated by the formula

$$Gb = \frac{Wf}{Vf}$$

in which Gb = the bulk specific gravity.

58. HARDNESS

Changes in the hardness are determined by cutting the trials with a knife blade or noting the relative hardness of the trials as compared with steel.

59. ABSORPTION

Absorption shall be reported as a percentage of the weight of the dry sample, and shall be obtained by dividing the weight of water absorbed, in grams, by the weight of the dry test piece, in grams.

60. PLOTTING RESULTS

When the results are plotted in graphical form (and this is advisable) heat treatment is preferably expressed in cone numbers. Under each cone number at which a trial is drawn, the reading of the temperature measuring instrument in degrees Centigrade shall be given. Equal distances on the abscissa and ordinate shall represent 2 cones and 5% porosity respectively. The same value of coördinates shall be used in expressing volume changes.

[1] For distinction between true, apparent, and bulk specific gravity see Sections 18, 19, and, 20, pp. 348–49.

X. TENTATIVE TEST METHODS

61. SAG TESTS

(A) Preface

The purpose of such a test as here defined is to determine the temperature and rate of softening under fixed conditions of load and heat treatment, as evidenced by transverse bending. For grogged mixtures that must support transversely applied load it supplies a direct test.

"Fine grog bodies" are understood as those containing grog finer than that which will pass a No. 20 sieve, and "coarse grog mixtures," those containing a grog of a coarser size, in any percentage.

(B) Method for Clay and Fine Grog Bodies

(1) Shape and Size The test pieces shall be bars measuring 12 mm. ($^1/_2$ inch) thick by 25 mm. (1 inch) wide by 230 mm. (9 inches) long when thoroughly dry.

(2) Making The bars shall be made in plaster molds by casting the clay slip to such thickness that when dry it will be somewhat thicker than 12 mm. ($^1/_2$ inch). This shall be allowed to dry slowly at room temperature until leather hard and then cut into strips somewhat wider than 25 mm. (1 inch) and longer than 230 mm. (9 inches). The oversize necessary will depend on the drying shrinkage of the clay. When thoroughly dry the bars shall be sized exactly by rubing or scraping.

(3) Setting The bars shall be set with the 25 mm. (1 inch) dimension, horizontal, in covered saggers. They shall rest on two fireclay knife edges spaced 177 mm. (7 inches) apart.

(4) Knife Edges It is recommended that the knife edges be triangular in cross-section and 45 mm. ($1^3/_4$ inches) high.

(5) Heat Treatment The test kiln shall be of such size that the effective space available is not less than $1^1/_2$ cubic feet. The heating may be accomplished by any convenient means, but the temperature distribution should be thoroughly explored during the first few firings. A set of pyrometric cones of the Seger formulas as made by Edward Orton, Jr., shall be placed as closely to the test pieces as possible, but temperature control by means of a platinum-platinum-rhodium thermocouple is required also. It is obvious that the kiln must be fired separately for each heat treatment.

The heating shall preferably be at the rate of 45°C per hour from the start of the firing until a temperature of 800°C is reached and 20°C from that point until the end of the firing. In no case shall the rate of

heating be greater than 60°C per hour or less than 30°C per hour for the first period, or greater than 25°C per hour or less than 15°C per hour for the last period.

(6) Number of Bars Two bars of the same clay shall be set for each heat treatment. The number of heat treatments is optional, but for data upon which to base conclusions on rate of softening, at least five heat treatments at two cone intervals shall be made.

(7) Warpage Ratio The amount of warpage shall be indicated by the ratio, to the second decimal place, of the amount of deflection in tenths of a millimeter to the span of 177 mm. (7 inches), and shall be the average of two bars.

(8) Variation If one bar shows a deformation more than 20% greater than the other, the test shall be considered faulty and the results discarded.

(C) Method for Coarse Grog Mixtures

(1) Shape and Size The test piece shall be 65 mm. ($2^1/_2$ inches) square and 330 mm. (13 inches) long when fired. A variation of plus or minus 3 mm. ($^1/_8$ inch) is allowable in the cross-sectional dimensions.

(2) Making The bars shall be made in a suitable mold. The mixture shall be made up to soft plastic consistency and thrown forcibly into the mold, so as to completely fill out the lower corners. The first lump shall be thrown in the center and then the ends filled in a similar manner. The excess shall then be struck off with a wire and the top of the bar slicked off with a spatula and appropriately marked. The bars shall then be thoroughly dried and fired to at least one cone higher than that at which warpage is to be determined. Such care shall be taken in setting that no warpage or sagging occurs in this preliminary firing.

(3) Setting The bars shall be set on flat fireclay supports with a span of 255 mm. (10 inches) and loaded in the center with a fireclay stirrup having a knife edge support. The load shall be 4.5 kg. (10 pounds) for bars of exactly 65 mm. ($2^1/_2$ inches) square cross-section. For bars within ± 3 mm. ($^1/_8$ inch) of these dimensions, the load shall be calculated as follows:

$$P = 0.0185\, bd^2$$

where P = load in kilograms
b = breadth of bar in centimeters
d = depth of bar in centimeters

or

$$P = 0.64\, bd^2$$

where P = load in pounds
b = breadth of bar in inches
d = depth of bar in inches.

(4) Heat Treatment The heat treatment shall be the same as specified above for clay and fine grog bodies.

(5) Number of Bars The number of bars shall be the same as specified above for clay and fine grog bodies.

(6) Warpage Ratio The warpage ratio shall be calculated as already specified for clay and fine grog bodies.

(7) Variation Allowable variation shall be the same as specified above for clay and fine grog bodies.

62. TRANSVERSE STRENGTH

(A) Preface

While a considerable amount of work has already been published in *Transactions of the American Ceramic Society* on this subject, it is still not sufficient to permit writing such definite specifications to cover this test as would be desired. However, the method which is presented below represents the best present practice, and will give quite consistent and reliable results as has been shown elsewhere.

(B) Method

(1) Preparation The clay shall be thoroughly dried at 64°C or above, but under 76°C, crushed and screened to pass a No. 20 sieve. It shall then be thoroughly mixed dry with an equal amount by weight of standard silica sand that passes a No. 20 sieve (Tentative Standard Series of Testing Sieves), and is retained on a No. 30 sieve. The mixture shall then be made up to soft plastic consistency with water and thoroughly pugged by hand.

(2) Shape The test piece shall be made in a suitable metal or wooden mold. It shall be 17.5 cm. (7 inches) long and have a 2.5 cm. (1 inch) square cross-section, in the plastic state.

(3) Forming The mold shall be evenly and thinly oiled with kerosene and placed on a firm, smooth surface. A lump of the clay mixture, somewhat larger than is required to fill the mold shall be thrown forcibly into the mold so as to completely fill out the lower corners. The excess shall then be cut off with a spatula, and the top slicked off and appropriately marked. The marking should be near the ends, so as not to deform the center of the bar.

(4) Drying The test pieces shall be allowed to dry under a cloth at room temperature for two days, then exposed at room temperature until air dry. During this period they shall be turned every twelve hours to make the drying more uniform. They shall then be placed in a drier operating between 64°C and 76°C for at least five hours, and from there transferred to a drying oven, operating at 110°C, where they shall remain until approximately constant in weight.

(5) Breaking The test pieces shall be cooled in a desiccator and then broken in a suitable machine, having knife edges with a 6 mm. ($^1/_4$ inch) radius and 12.5 cm. (5 inches) apart. The machine should have an automatic shutoff for the shot, and the rate of loading should be about 45 kg. (100 lbs.) per minute. The depth and breadth of the bar shall be taken at the break, and each shall be the average of three measurements taken to the nearest 0.25 mm. (0.01 inch).

(6) Modulus of Rupture The modulus of rupture shall be calculated by the formula

$$M = \frac{3Pl}{2bd^2}$$

where M = modulus of rupture in kg. per sq. cm.
P = breaking load in kg. (read to the nearest 0.1 kg.)
l = distance between knife edges in cm.
b = breadth of bar in cm.
d = depth of bar in cm.

or, if the English system is used, the units will be pounds and inches, and the modulus will be obtained in pounds per square inch, by the same formula.

Ten bars shall be broken and the average modulus of rupture reported. Two faulty test pieces are permissible in the case of which, the average of the eight or nine remaining shall be reported.

(7) Variation A variation of plus or minus 15% from the average modulus of rupture is permissible. Test pieces showing a greater variation shall be considered faulty and discarded; but as indicated in (6) preceding, if more than two are thus discarded, the test shall be repeated.

63. RESISTANCE OF FIRECLAY BRICK TO THERMAL SPALLING ACTION

(Same as Serial Designation: C38–27T A.S.T.M.)

(1) The object of this test is to determine the resistance of high-duty fireclay brick to spalling action, by subjecting them to repeated rapid temperature changes.

(2) (*a*) The sample shall consist of at least five standard 9-in. brick or of five shapes, which may be cut to standard size with a grinding wheel.

(*b*) Test specimens of shapes such as boiler arch brick shall be cut to the standard 9-inch size. For this purpose a "cut-off" wheel is recommended.

(3) (*a*) The specimens shall be weighed and placed in a door of a

furnace operated at 1350°C (2462°F), care being taken to prevent the direct heating of more than the $2^1/_2$- by $4^1/_2$-inch end. After one hour the specimen shall be withdrawn from the furnace and stood on end in a tank of flowing cold water from 10 to 21°C (50 to 70°F) so that the hot end of the brick will be immersed to a depth of 2 inches. After three minutes the sample shall be withdrawn from the water, allowed to steam five minutes and then returned to the furnace. The door of the furnace shall be closed while the brick are out to prevent the lowering of the temperature. The alternate heating and cooling shall be continued in hourly cycles until a loss of 20% has occurred in each brick.

(*b*) When pieces begin to fall off, the sample is laid on a 4.5- by 9.0-inch asbestos board, divided into one hundred equal squares, and the approximate percentage of loss estimated after each removal from the water. After the completion of the test, the brick is again weighed and the percentage of loss determined.

(4) The report shall show for each brick the number of dips before loss started, the percentage of loss after each cooling, and the total number of dips until a loss of 20% by weight has occurred.

64. TEST FOR REFRACTORY MATERIALS UNDER LOAD AT HIGH TEMPERATURES

(This test has been issued by the American Society for Testing Materials under the Serial Designation C16–20.)

(1) The object of this test is to determine the resistance of the specimen to deformation at a specified temperature for a specified time, when subjected to a compressive load of 25 lb. per sq. in. (1.765 kg. per sq. cm.).

(2) The apparatus consists essentially of a furnace and loading device. It shall be constructed in accordance with Fig. A7. (See Appendix.)

(*a*) The furnace shall be cylindrical in form, 18 in. (457 mm.) in internal diameter, as shown in Fig. A7. (See Appendix.)

(*b*) The heating shall be done with gaseous or oil fuel and compressed air, using not less than two burners located tangentially and so arranged that no flame can impinge upon the test specimen. The burners shall be such as will insure a universal temperature in all parts of the furnace and be under complete control.

(*c*) The method of loading shown in Fig. A7 shall be used, and the details shall be such as will insure accuracy in the applied load and freedom from eccentric loading, both in the original application and during the testing. It is advantageous to make the cross-beams as

light as possible, so that the greater portion of the load may be concentrated in the weights.

TABLE I

TEMPERATURE TO BE ATTAINED AT TIME SPECIFIED

(All Temperatures in Degrees Centigrade)

Time Hr.	Min.	Silica	Fire Clay		
			Heavy duty	Moderate duty	Light duty
	15	40	160	160	160
	30	80	280	280	280
	45	140	400	400	400
1	0	200	500	500	500
	15	260	620	595	570
	30	290	720	685	640
	45	300	815	770	700
2	0	310	900	850	755
	15	320	980	920	810
	30	385	1045	990	860
	45	490	1100	1050	905
3	0	590	1150	1100	950
	15	695	1195	1145	985
	30	800	1235	1185	1020
	45	900	1270	1220	1050
4	0	1000	1300	1250	1075
	15	1100	1330	1275	1090
	30	1200	1350	1300	1100
	45	1250	1350	1300	1100
5	0	1300	1350	1300	1100
	15	1350	1350	1300	1100
	30	1380	1350	1300	1100
	45	1410	1350	1300	1100
6	0	1440	1350 (end)	1300 (end)	1100 (end)
	15	1470			
	30	1500			
	45	1500			
7	0	1500			
	15	1500			
	30	1500			
	45	1500			
8	0	1500 (end)			

(*d*) The temperature may be measured either with a calibrated platinum-rhodium thermocouple, encased in a double protecting tube with the junction not more than one inch (25 mm.) from the side or edge of the specimen and approximately opposite the center; or with some form of optical pyrometer that has been calibrated against a thermocouple in the furnace. If the thermocouple is used, the cold-end temperature should be kept constant in melted ice. A recording form of indicator is recommended where possible.

(3) The test specimen shall consist, whenever possible, of a standard 9-inch brick placed vertically on end. In the case of blocks or shapes, sections approximately 9 by $4^1/_2$ by $2^1/_2$ inches (228 by 114 by 64 mm.) shall be cut, utilizing as far as possible existing plane surfaces. The ends of the specimen shall be either ground so that they are parallel and perpendicular to the vertical axis, or if this is impossible, shall be bedded in a neutral cement, so that the specimen is perpendicular to the base of the furnace.

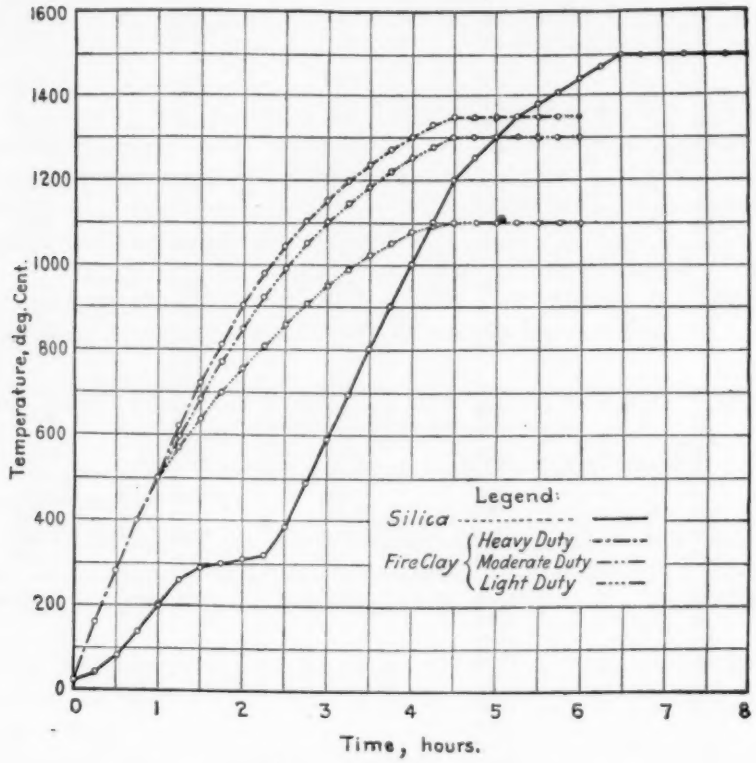


FIG. 1.—Time-temperature curve for load test.

Note.—Gross error which may more than double the contraction will result if the specimen is not set perpendicular to the base of the support or if the load is eccentrically applied.

The test specimen shall be measured before testing, making not less than five observations in each direction to within ± 0.02 inch (0.5 mm.). The average dimensions shall be reported, and the cross-section calculated.

(4) The test specimen shall occupy approximately the center of the furnace and should rest on a block of some highly refractory material,

having a minimum expansion or contraction. A silicon-carbide brick has been found satisfactory. At the top of the test specimen a block of similar highly refractory material should be placed, extending through the furnace top to receive the load.

(5) The rate of heating shall be in accordance with the requirements of Table I, p. 463, and the time-temperature curves of Fig. 1, which give the rate and time of heating suggested for different grades of material.

(6) (*a*) The load is calculated from the average cross-section as determined on the untested specimen and the requirement of the test. It is recommended that for general purposes, 25 lb. per sq. in. (1.765 kg. per sq. cm.) be used.

(*b*) The additional masses required to give the desired loading should be equally distributed on each side of the beam.

(7) (*a*) At the expiration of the time of heating, the supply of heat shall be stopped and the furnace allowed to cool, during not less than 5 hours before removing the load and examining the test specimen.

Note.—The specimen shall be examined immediately after the heating is stopped for evidences of cracking and spalling, as such defects may develop later due to the rapid cooling of the furnace.

(*b*) After the test specimen has cooled to the room temperature, it shall be remeasured as before described, and the change in length recorded and reported as percentage of the original length.

Note.—It is recommended that a photograph be made of the specimen before and after testing, as yielding valuable information at a minimum time and expense.

65. DEFORMATION TEMPERATURE OF ENAMEL[1]

This method is applicable to frits and milled enamel.

(1) Preparation of Sample A representative sample of frit or milled enamel shall be thoroughly dried and ground in a porcelain pebble mill to pass a 150-mesh sieve.

(2) Test Pieces The test pieces shall be the size and shape of pyrometric cones; tetrahedra $^5/_8$ inch along the edge of the base and $2^1/_2$ inches high. They shall be molded from a mixture of the powdered enamel and water with enough organic binder to produce the necessary plasticity and cohesion. The test pieces shall be thoroughly dried upon removal from the molds.

(3) Mounting The test pieces shall be mounted on a plaque of asbestos board or strip of sheet steel which has been coated with enamel. The base of the test pieces shall be imbedded in a plastic mixture such as sand, clay, and water, and their troweled

[1] For full Report see *Bull. Amer. Ceram. Soc.*, **6** [9], 259–80 (1927). Reprint copies on this Report may be obtained on request to Office at the General Secretary, AMERICAN CERAMIC SOCIETY.

faces shall make an angle of 82° with the plaque. Two test pieces from the same sample shall be placed on a given plaque in such a manner as to face in the same direction and permit the end of the thermocouple being between the tips of the test pieces without being touched thereby during deformation. The mounting shall be thoroughly dried before being placed in the furnace.

(4) Furnace The furnace shall be one which shall give a definitely oxidizing atmosphere. It shall be subject to accurate temperature control through the range 800–1600°F. It shall be equipped with a pyrometer the thermocouple of which shall terminate near the center of the horizontal plane of the furnace and one inch or further below the top. The pyrometer shall be of such type as to afford an accuracy of ±5°F, with proper corrections for cold end temperature.[1]

(5) Placing of Test Pieces in Furnace The mounting shall be placed in the furnace in such a manner that the tips of the test pieces shall be 1/2 inch above the center of the thermocouple and horizontally equidistant therefrom.

(6) Rate of Heating The furnace shall be at or below 800°F when the test pieces are placed therein. The rate of heating shall be the following:

Start	800°F
10 min.	1020
20 "	1150
30 "	1260
40 "	1370

(7) Observations Each test piece shall be observed separately with reference to the temperature of initial bending of the tip and final bending of the tip to the level of the base. The first observations shall be averaged as the "starting temperature" and the final as the "deformation temperature." The difference between the two shall be taken as the "deformation range." Two or more closely checking runs shall be averaged for final results.

66. FINENESS OF WET-MILLED ENAMEL[2]

(1) Sample The enamel to be tested shall be thoroughly stirred to produce uniformity. A 100-gram sample shall be weighed.

(2) Sieves A No. 40 sieve shall be placed above a No. 200 screen. The numbers refer to the Standard Screen Scale and correspond approximately to the number of meshes per linear inch. The actual sieve openings are .0166 and .0029 inch respectively.

[1] Later consideration by the Committee resulted in a suggestion that the accuracy be stated as "±10°F."

[2] See footnote on p. 465.

(3) Testing The weighed sample shall be poured onto the upper sieve and carefully washed through the two sieves with water until no enamel can be detected in the washings. Nothing other than coarse, unground particles shall be retained on the upper sieve which serves as a protection for the under sieve. The lower sieve with its residue shall be thoroughly dried until the residue thereon easily moves about as a dry powder when the sieve is shaken. The sieve shall be gently tapped until no more dry powder passes through.

(4) Weighing The residue shall be transferred to a balance and weighed to the nearest 0.1 gram. The weight thus determined shall be taken as the index of fineness of the enamel.

XI. METHODS OF TESTING ELECTRICAL PORCELAIN[1]

(A.S.T.M. Designation D116–27T)

These tests are intended to apply to porcelain which is to be used for electrical insulating purposes.

67. TENSILE STRENGTH

(1) Any standard testing machine of suitable capacity may be used providing the error in the loading range does not exceed 1%.

(2) (*a*) The test specimens for this test shall be of the form and dimensions shown in Fig. 1.

(*b*) For wet-process porcelain, the test specimens shall be made from a column obtained by forcing the batch mixture through a die. Sections of the column, after thorough drying, shall be formed to the required shape with due allowance for shrinkage. During the firing, care shall be taken to maintain the axis perfectly straight.

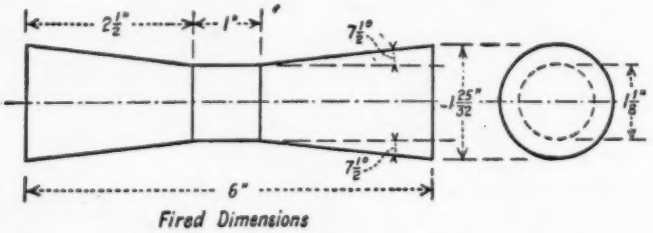


FIG 1.—Test specimen for determining tensile strength of porcelain.

(*c*) For cast porcelain, the specimens shall be cast in molds of calcined gypsum (plaster of Paris) having the required shape, due allowance being made for all shrinkages. None of the material except the fins shall be removed from the specimen.

(*d*) For dry-process porcelain, the specimens shall be formed by pressure into the required shape in metal molds with due allowance for all shrinkages.

(3) (*a*) Suitable grips for holding the specimen shall be self-aligning and shall grip the specimen over sufficient area and in a manner not to cause pinching near the minimum section nor local compression at the smaller ends of the metal grips. Grips designed for the purpose and found satisfactory are shown in Fig. 2. In principle they are arranged like gimbals or a universal joint used for maintaining a mariner's

[1] Issued, 1921; Revised, 1924, 1926.

compass in position. A yoke allows a ring to swing about a horizontal axis. A smaller ring is situated inside the first one but pivoted by means of pins in a plane perpendicular to the horizontal axis. The inner ring is conically shaped and holds the porcelain specimen in place with the aid of the split bushings. The two yokes are placed in the testing machine at right angles to each other.

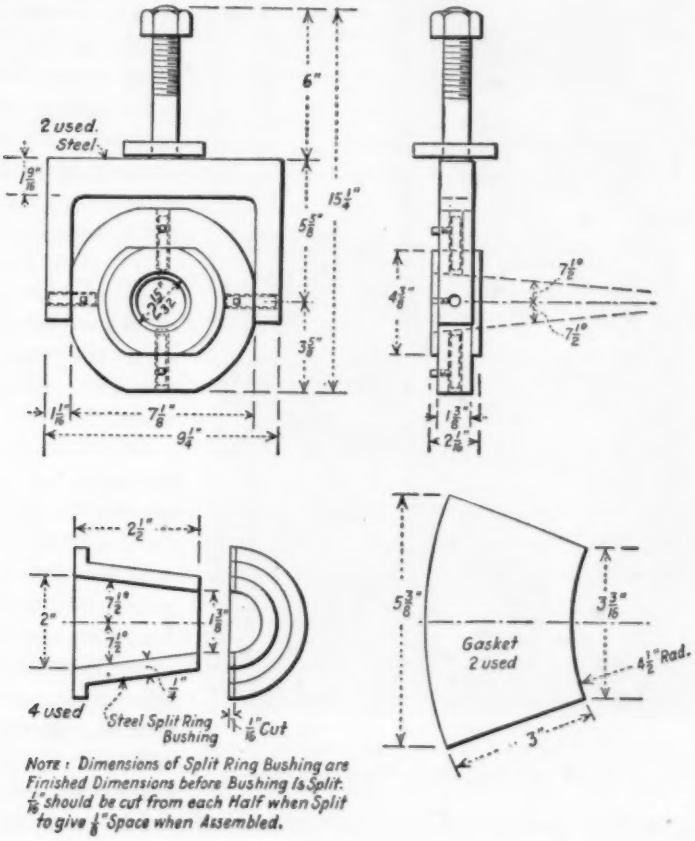


FIG. 2.—Grips for tension testing of porcelain.

(*b*) The test specimen shall be fitted with a compressible gasket around each conical end with the parallel edges nearly touching. Blotting paper or sheet lead 1/32 in. thick has been found satisfactory. The gasket may be held in place, while assembling the test specimen in the grips, by a temporary clamp at the place of minimum section. After the specimen has been assembled in place ready for test, the

temporary clamp shall be removed. A disassembled view of the apparatus is shown in Fig. 3.

Procedure

(4) (*a*) Not less than five specimens shall be tested in the normal condition.

(*b*) The diameter of each specimen at the minimum section shall be measured with a micrometer graduated to 0.001 inch (0.025 mm.). The value of the diameter to be used in the calculation shall be the average of two measurements taken at right angles.

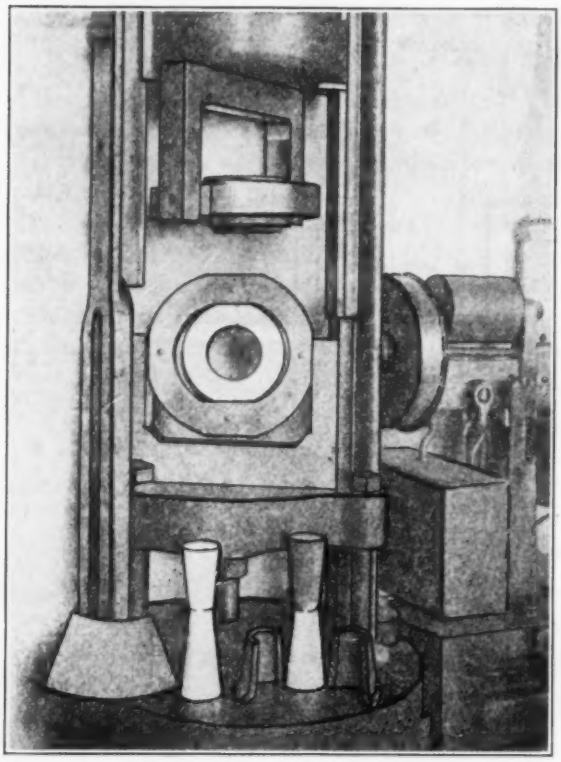


FIG. 3.—Apparatus for tension testing of porcelain including grips, specimen split ring, and blotting paper gasket.

(*c*) The speed of head of the testing machine shall be such that the load can be accurately weighed.

(*d*) The tests shall be made at a temperature of about 21°C (70°F).

(*e*) Results on specimens which do not break in the section of minimum cross-section shall be included, though the unit stress shall be calculated using the minimum cross-section. Any results whose deviation from the mean of the deviations is more than 3 times the mean of the deviations shall be discarded.

(5) The report shall include the following:

(*a*) The breaking load of each specimen in pounds.

(*b*) The diameter of each specimen in inches at the place of break and at the minimum section.

(*c*) The tensile strength of each specimen in pounds per square inch.

(*d*) The average of the results given in (*c*) and the percentage average deviation from the mean.

(*e*) A description of each fracture and the behavior of the material under load. The description of the fracture should tell whether the fractured area was totally or partially rough, and whether pin holes or other flaws were found.

Note.—An examination of the fracture of a normal specimen will show the entire area to consist of a very coarse granular surface, indicating that the entire area was subjected to tension and that the entire surface resisted it. In a specimen containing a pin hole or other flaw, the fracture will usually start near that flaw or pass through it. Part of the surface further away from the flaw will be granular, but the surface near the flaw will be much smoother. If the specimen is compressed at a narrow portion near one of the grips, the surface is again divided into two distinct areas, the area of tension and the area of shear, the latter radiating from the spot which was most under compression.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the tensile strength in pounds per square inch of each specimen, the first value being the lowest and each succeeding one the next higher.

68. COMPRESSIVE (CRUSHING) STRENGTH

(1) Any standard-testing machine of suitable capacity may be used providing the error in the loading range does not exceed 1%.

(2) The test specimens for this test shall be in the form of cylinders and shall be 1.125 inches (2.86 cm.) in length and 1.125 inches (2.86 cm.) in diameter.

(3) They shall be made as described in Section 67 (2*a*–*d*) (p. 468). The flat surfaces shall be made as smooth and parallel as possible before firing. After firing, the flat surfaces shall be ground smooth and parallel.

(4) Not less than five specimens shall be tested in the normal condition.

(*b*) A contact pad or cushion of blotting paper $^1/_{64}$ inch thick shall be placed between the upper and lower faces of the specimen and the self-aligning heads of the testing machine to equalize irregularities in the surfaces. Fresh cushions shall be used for each specimen.

(*c*) The diameter and length of each specimen shall be measured with a micrometer graduated to 0.001 inch (0.025 mm.). The value of the diameter to be used in the calculations shall be the average of two measurements taken at right angles.

(*d*) The speed of head of the testing machine shall be such that the load can be accurately weighed.

(*e*) The tests shall be made at a temperature of about 21°C (70°F).

(5) Note shall be made of the load in pounds at initial failure but the value of the load in pounds at ultimate failure shall be determined and used in calculating the compressive (crushing) strength.

(6) The report shall include the following:

(*a*) The load in pounds on each specimen at initial failure and the load in pounds at ultimate failure.

(*b*) The diameter and length of each specimen in inches.

(*c*) The compressive (crushing) strength of each specimen in pounds per square inch.

(*d*) The average of the results given in (*c*) and the percentage average deviation from the mean.

(*e*) The behavior of the material under load.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the compressive strength in pounds per square inch of each specimen, the first value being the lowest and each succeeding one the next higher.

69. TRANSVERSE STRENGTH

(1) Any standard testing machine of suitable capacity may be used.

(2) (*a*) The test specimens for the transverse strength test shall be in the form of cylinders and shall be 6 inches (15.2 cm.) in length and 1.125 inches (2.86 cm.) in diameter.

(*b*) They shall be made as described in Section 67 (2*a*–*d*) (p. 468).

(3) The specimen shall be supported on two steel wedge-shaped blocks with supporting edge rounded to 0.125 inch (3.175 mm.) radius. The supports shall be 5 inches (127 mm.) apart and the specimen shall be laid upon them with $^1/_2$ inch (12.7 mm.) overlap at each end. The load shall be applied on top of the specimen at right angles to the specimen and midway between the supports by means of a wedge-shaped pressure piece (angle 45°), the edge of which is rounded on a 0.125 inch (3.175 mm.) radius.

(4) (*a*) Not less than five specimens shall be tested in the normal condition.

(*b*) The diameter of each specimen shall be measured with a micrometer graduated to 0.001 inch (0.025 mm.). The value of the diameter to be used in the calculations shall be the average of two measurments taken at right angles at the middle of the specimen.

(*c*) The load shall be applied at that constant rate of speed which will permit the beam to be kept well balanced at all loads.

(*d*) The tests shall be made at a temperature of about 21°C (70°F).

(5) The modulus or rupture shall be calculated for each specimen as follows:

$$M = \frac{8PL}{\pi d^3}$$

where M = modulus of rupture
P = load in pounds at rupture
L = distance between supports in inches
d = diameter of specimen in inches
$\pi = 3.1416$.

(6) The report shall include the following:

(*a*) The breaking load of each specimen in pounds.

(*b*) The diameter and length of each specimen in inches.

(*c*) The modulus of rupture for each specimen as calculated in paragraph (5) p. 472.

(*d*) The average of the results given in (*a*) and the percentage average deviation from the mean.

(*e*) A description of each fracture and the behavior of the material under load.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the transverse strength (modulus of rupture) for each specimen, the first value being the lowest and each succeeding one the next higher.

70. RESISTANCE TO IMPACT[1]

(1) The test shall be made with an apparatus in which a weight of 1 pound is raised $^1/_2$ inch and allowed to fall on the specimen. It is then raised 1 inch and allowed to fall again on the specimen. This is continued, the weight being raised and dropped through a distance increasing by increments of $^1/_2$ inch until the specimen is broken.

(2) The test specimen described in Section 68 (2) (p. 471) shall be used for impact tests.

(3) (*a*) The test specimen shall be clamped in the base of the impact tester directly under the hammer. The stops shall be set to give a successively increasing rise of hammer by $^1/_2$-inch increments, the first height being $^1/_2$ inch.

(*b*) The entire hammer shall weigh 1 pound.

(*c*) The test shall be continued until the specimen cracks.

(*d*) Not less than five specimens shall be tested in the condition in which which they are received.

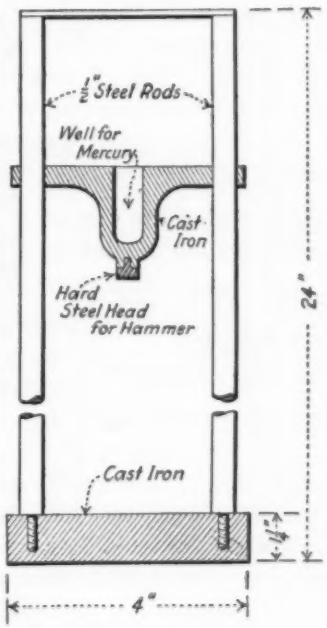


FIG. 1.

(4) The report shall include the number of blows required to break each specimen, the energy of each blow in

[1] See also Test Apparatus and Method, A12, p. 508.

inch-pounds and the total energy in inch-pounds (that is, the sum of all blows).

Note.—The apparatus may be a simple hand-operated one (See Fig. 1.) or a motor-operated machine where the weight is lifted and the distances are increased automatically.

71. DIELECTRIC STRENGTH[1]

(1) The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Insulating Materials (Serial Designation: D 48) of the American Society for Testing Materials. (See Section 67 (3) p. 468).

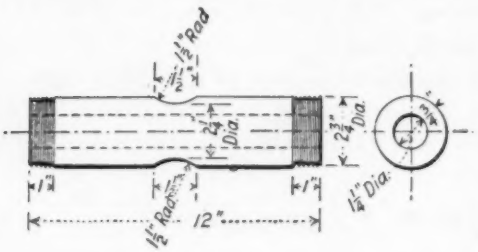


FIG. 1.

(2) The specimens shall be as shown in Fig. 1 except that the threads may be omitted.

(3) (a) Porcelain for All Purposes A pad of wet clay about 1/4 in. thick shall be laid in the groove and a lining of wet clay about 1/4 in. thick put on the inside of the specimen. The potential shall be applied to these two pads of clay by any suitable means. Mercury may be substituted for the wet clay if desired. The test should preferably be made in air but it may be made in transformer oil if necessary.

Not less than ten specimens shall be punctured in their normal condition at a normal room temperature of about 20°C (68°F).

(b) Porcelain for Transmission Line Insulators In addition to the test prescribed in paragraph (*a*), not less than 10 specimens shall be tested in the same manner at a temperature of 75°C (167°F).

(c) Porcelain for Spark Plugs In addition to the test prescribed in paragraph (*a*), not less than 10 specimens shall be tested to determine the effect of high temperatures on the dielectric strength. The specimens shall be placed in an electrically heated oven the temperature of which can be raised at a constant rate to 600°C (1112°F). A given voltage shall be applied and maintained constant and the temperature raised at any constant rate such that the porcelain is always practically at the temperature of the air. The temperature shall be raised until puncture occurs.

(*d*) Whenever a puncture occurs at a point other than the minimum section of the specimen in any of the tests prescribed above, that result shall be discarded.

(4) The report shall include the following:

[1] See Test Apparatus and Method, A13, p. 511.

(*a*) A statement of the purpose for which the porcelain is intended and the kind of tests which were made.

(*b*) The thickness of the specimen at the bottom of the groove.

(*c*) The voltage at puncture for each of the test specimens together with the average, maximum and minimum volts per mil or per millimeter of thickness.

72. RESISTANCE TO THERMAL CHANGE

(A) Porcelain for Transmission Line Insulators

(1) The apparatus shall consist of a hot-water bath maintained at a temperature of 100°C (212°F) and an ice-water bath maintained at 0°C (32°F).

(2) The test specimens shall be as shown in Fig. 1 (p. 474).

(3) (*a*) The test specimen shall be immersed in the ice-water bath for ten minutes and then transferred as quickly as possible to the hot-water bath, and allowed to remain there for ten minutes. The specimen shall be transferred back to the cold water and the cycles continued until the specimen breaks.

(*b*) Not less than five specimens shall be tested.

(4) Report the number of cycles necessary to cause fracture of each test specimen.

(B) Porcelain for Spark Plugs and Heating Devices

(1) A furnace in which a temperature of 900°C (1652°F) can be obtained and any suitable testing machine for determining the transverse strength of small beams may be used.

(2) The specimens shall be as described in Section 69 (2) (p. 472).

(3) (*a*) One-half of not less than 12 specimens shall be taken and placed in the furnace. The rate of heating shall be so adjusted that the temperature reaches 900°C (1652°F) in two hours. The furnace shall then be allowed to cool at such a rate that room temperature is reached in four hours.

(*b*) All specimens for transverse strength shall be tested by placing them on supports 5 inches apart and loading them at the center.

(4) The report shall include the following:

(*a*) The load in pounds or kilograms required to break each specimen not subjected to heat treatment, together with the average.

(*b*) The load required to break each specimen that was subjected to heat treatment, together with the average.

(*c*) The percentage loss of strength due to heat treatment calculated from the two averages.

73. POROSITY[1]

Water Absorption

(1) Any good chemical balance, a beaker of distilled water at normal room temperature of about 20°C (68°F) and an oven of any standard make capable of maintaining a uniform temperature at the desired point within ±5°C shall be provided.

(2) A single piece of porcelain shall be used weighing from 30 to 50 g. and with at least 50% of the surface newly fractured.

(3) The specimen shall be dried for 24 hours at 120°C (248°F), cooled in a desiccator, and weighed. The specimen shall then be totally submerged in the distilled water at room temperature (about 20°C) and allowed to remain submerged for 100 hours. The water shall be boiled for approximately one hour during the first, twenty-fifth, forty-ninth, and seventy-third hours. The specimen shall be removed at the end of the 100-hour period, the surface moisture carefully dried off with a clean, dry cloth and the specimen weighed.

(4) The report shall include the following:

(*a*) Original weight of the specimen.

(*b*) Dry weight of the specimen.

(*c*) Dry weight of the specimen after immersion for 100 hours.

(*d*) Percentage of moisture content in each specimen as received and the percentage of moisture absorbed during 100 hours, taking the dry weight as 100%, and the average where more than one specimen is tested.

[1] See also Test Apparatus and Methods, A4, A5, and A6, pp. 494, 496, and 499.

XII. METHODS OF TESTING BRICK

(Same as Serial Designation: C67-27T A.S.T.M.)

These methods cover the following tests for brick: (*a*) the compression test, (*b*) the flexure or cross-bending test, and (*c*) the rattler test.

74. COMPRESSION TEST

(A) Apparatus

(1) Any form of standard testing machine may be used for the compression test together with a spherical bearing block large enough entirely to cover the specimen.

(B) Test Specimen

(1) The test specimen shall consist of a half-brick. Any method which will produce a specimen with approximately plane and parallel ends, without shattering the specimen, may be used.

Note.—This permits the use of a suitable half-brick from the flexure test.

(2) A half-brick to be used for the compression test shall be prepared as follows: The two surfaces intended to receive the load from the testing machine shall receive a thin coating of shellac and be

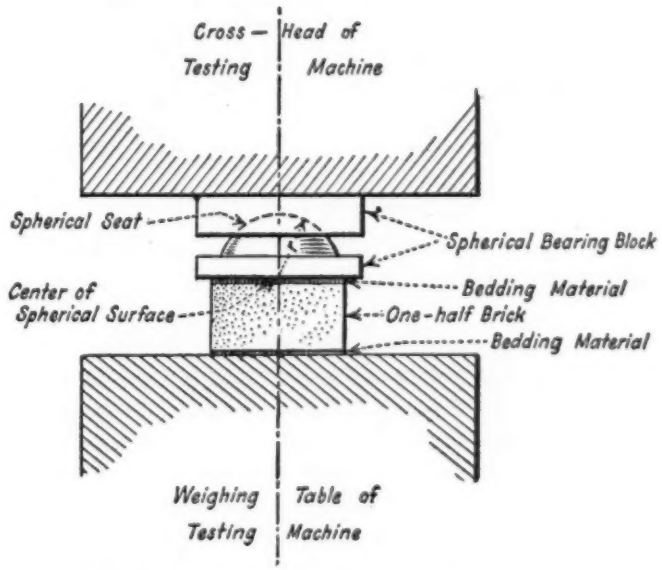


FIG. 1.—Special bearing block for use in testing brick.

allowed to dry thoroughly. One of the shellacked bearing surfaces shall then receive a thin coat of a neat mortar of calcined gypsum (plaster of Paris). This mortared face of the specimen shall then be pressed on plate glass or a machined metal plate, previously oiled or covered with waxed paper, and the bedding material allowed to harden. This procedure shall be repeated with the other shellacked surface. Care shall be taken that the opposite faces so coated with bedding material shall be parallel. Depressions of recessed or panelled bricks shall be filled with neat Portland-cement mortar which shall stand at least 24 hours before testing.

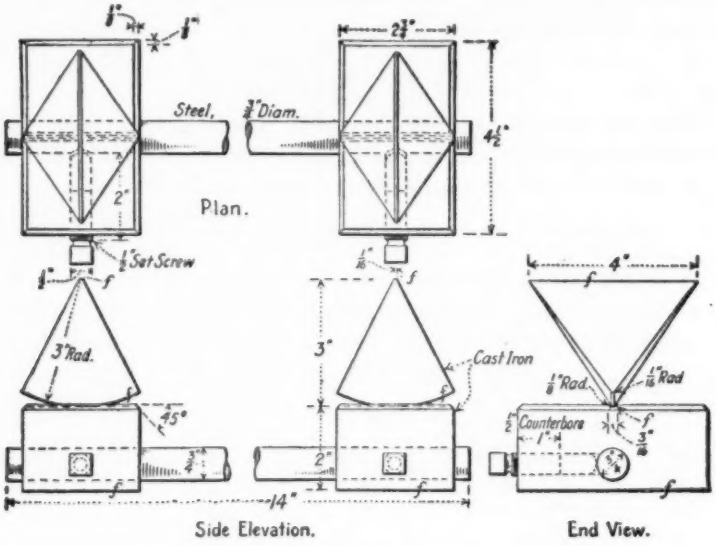


FIG. 2.

(3) Compression tests shall be made on at least five half-brick test specimens from different bricks.

(C) Procedure

(1) (*a*) The half-brick test specimen shall be tested, placed flat.

(*b*) The bearing block shall be used on top of the test specimen in vertical testing machines. The center of the sphere of the bearing block shall be used in contact with the top bearing surface of the specimen, and in the vertical axis of the specimen. (Fig. 1.) The spherical bearing block shall be kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load.

(*c*) The speed of the moving head of the testing machine, during the application of the load shall not be more than 0.05 inch per minute.

(*d*) During the test the beam of the testing machine shall be kept constantly in a floating position.

(2) The compressive strength in pounds per square inch shall be reported as the total maximum load, W, in pounds, indicated by the testing machine, divided by the area, A, in square inches, of the minimum section of the specimen perpendicular to the line of application of the load.

The compressive strength in pounds per square inch shall be calculated from the formula

$$\text{Compressive strength} = \frac{W}{A}$$

75. FLEXURE TEST

(A) Apparatus

(1) (*a*) Any form of standard testing machine with knife edges as described in paragraph (*b*) may be used for the flexure test.

Note.—Portable apparatus properly calibrated may be used.

(*b*) Knife edges shall be straight and have full contact with the specimen or bearing plate and they shall have a length at least equal to the width of the brick to be tested. Their bases shall be so curved or rounded as to permit free movement of the working edges, both longitudinally and transversely. The use of knife edges of the type shown in Fig. 2 (p. 478) is recommended, although other types may be used which will provide free movement and at the same time insure full and even bearing at all times during the test.

(B) Test Specimen

(1) The test specimen shall be a whole brick.

(2) Flexure tests shall be made on at least five whole bricks.

(C) Procedure

(1) (*a*) A test-specimen brick shall be placed flat-wise on the knife edges with a span of 7 inches and the load applied at mid-span.

(*b*) A steel-bearing piece $^1/_2$ inch square and of a length equal to the full width of the specimen shall be placed between the upper knife edge and the specimen.

(*c*) The speed of travel of the head of the testing machine, during the application of the load, shall not be more than 0.05 inch per minute.

(2) The modulus of rupture, R, in pounds per square inch shall be reported as calculated from the following formula:

$$M = \frac{3Pl}{2bd^2}$$

where P = the total load in pounds at which the brick failed
l = the distance between the supports in inches
b = the width of the brick in inches
d = the depth of the brick in inches.

76. RATTLER TEST

(A) Apparatus

(1) The machine used in the rattler test shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame, and driving mechanism as described in paragraphs (2) to (6) pp. 480 to 481. In Fig. 1 is illustrated[1] a rattler which will meet the requirements specified, and to which reference should be made.

(2) The barrel of the machine shall consist of the heads, headliners, staves, and staveliners conforming to the following requirements:

(a) Heads The heads may be cast in one piece with the trunnions which shall be $2^{7}/_{16}$ inch in diameter, and shall have a bearing 6 inches in length; or they may be cast with heavy hubs, which shall be bored out for $2^{7}/_{16}$-inch shafts and shall be keyseated for two keys, each $^{1}/_{2}$ by $^{3}/_{8}$ inch and spaced 90° apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15^{3}/_{8}$ inches in the head for the driving end of the rattler and $11^{3}/_{8}$ inches for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5^{1}/_{8}$ inches.

The heads shall not be less than $^{3}/_{4}$ nor more than $^{7}/_{8}$ inch in thickness. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28^{3}/_{8}$ inches in diameter. Each head shall be provided with flanges not less than $^{3}/_{4}$ inch in thickness and extending outward $2^{1}/_{2}$ inches from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing, the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $^{3}/_{4}$-inch bolts at each end of each stave, the slots to be $^{13}/_{16}$ inch in width and $2^{3}/_{4}$ inches center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two

[1] See insert, p. 481*a*.

slots there shall be a brace $^3/_8$ inch in thickness extending down the outward side of the head not less than 2 inches.

(b) Headliners There shall be for each head a cast-iron headliner, 1 inch in thickness and conforming to the outline of the head, but inscribed in a circle $28^1/_8$ inches in diameter. This headliner shall be fastened to the head by seven $^5/_8$-inch cap screws, through the head from the outside. Whenever these headliners become worn down $^1/_2$ inch below their initial surface level, at any point of their surface, they shall be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than 1% of combined carbon.

(c) Staves The staves shall be made of 6-inch medium-carbon steel structural channels $27^1/_4$ inches in length and weighing 15.5 pounds per lineal foot. The staves shall have two holes $^{13}/_{16}$ inch in diameter, drilled in each end, the center line of the holes being 1 inch from the end and $1^3/_8$ inch either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed $^5/_{16}$ inch.

(d) Staveliners The interior or flat side of each stave shall be protected by a liner $^3/_8$ by $5^1/_2$ by $19^3/_4$ inches. The liner shall consist of a medium-carbon steel plate, and shall be riveted to the channel by three $^1/_2$-inch rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 inches from the center each way. The rivet holes shall be counter-sunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

(3) When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 pounds of shot of the same sizes, and in the same proportion as provided in paragraph (7*a* and *b*) (p. 482), and shall then be run for 1800 revolutions at the rate of speed specified in paragraph (1*a*) (p. 483). The shot shall then be removed and a standard shot charge inserted after which the rattler may be charged with brick for a test.

(4) No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive, but not contiguous: for example, 1 and 8, 3, and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative conditions of repair. The changes in the staves

should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new-lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 inches in length, inside measurement, between headliners. The liners of the staves shall be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four $^3/_4$-inch bolts and each bolt shall be provided with a locknut and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

(5) The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

(6) The barrel shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1^{15}/_{16}$ inches in diameter, with bearing not less than 6 inches in length. If a belt drive is used, the pulley shall be not less than 18 inches in diameter and $6^1/_2$ inches in face. A belt at least 6 inches in width, properly adjusted, to avoid unnecessary slipping, should be used.

(7) The abrasive charge shall consist of cast-iron spheres of two sizes.

(a) Large Spheres When new, the larger spheres shall be 3.75 inches in diameter and shall weigh approximately 7.5 pounds (3.40 kg.) each. Ten spheres of this size shall be used. These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 pounds (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that insofar as possible the large spheres shall compose a graduated series in various stages of wear.

(b) Small Spheres When new, the smaller spheres shall be 1.875 inches in diameter and shall weigh approximately 0.95 pound (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 pounds as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 inches in diameter, drilled in an iron plate $^1/_4$ inch in thickness, or weigh less than 0.75 pound (0.34 kg.).

Further, the small spheres shall be tested by passing them over the

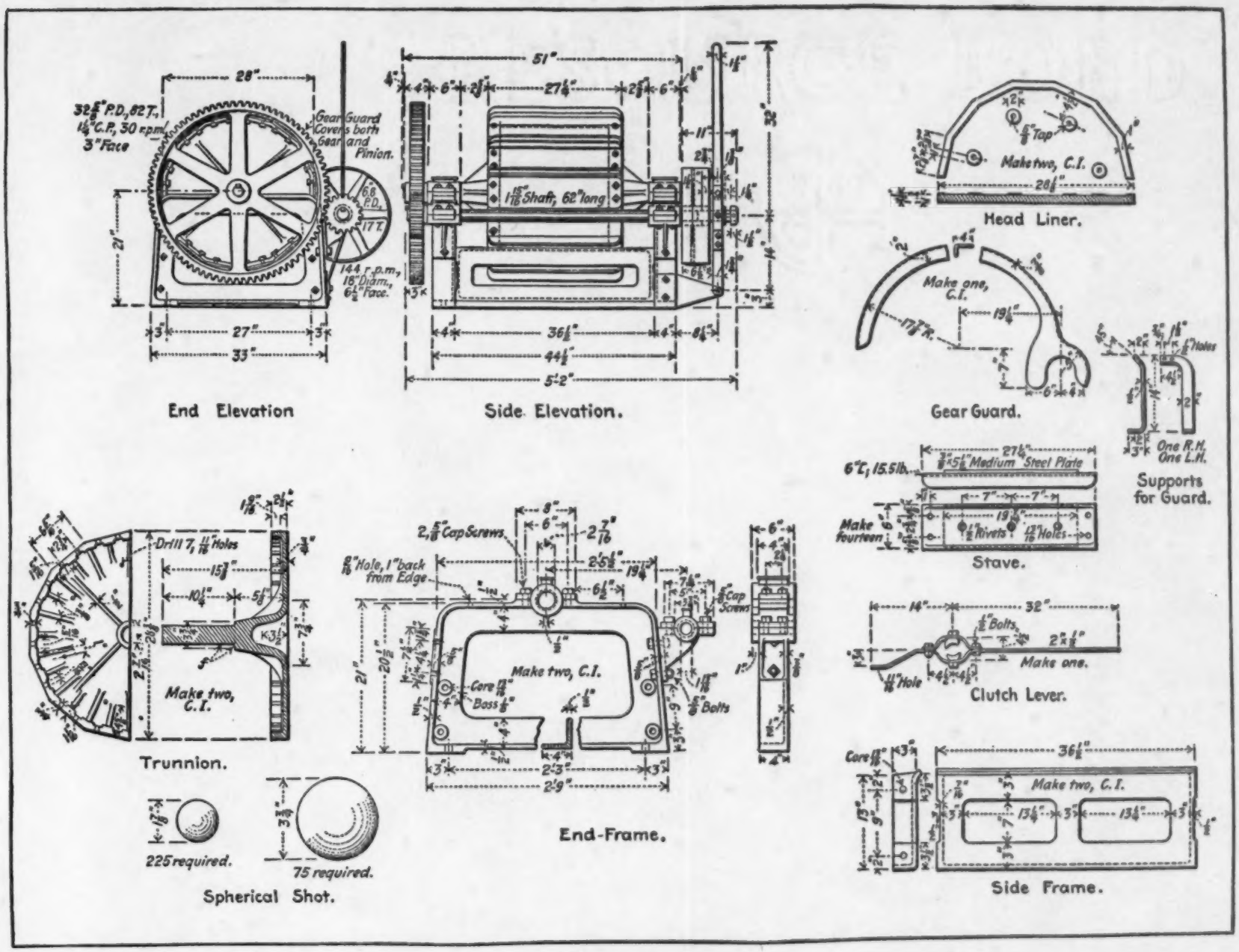


FIG. 1.—Details of rattler for testing brick.

plate mentioned or by weighing, after every ten tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres, provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

(8) The cast-iron abrasive spheres shall conform to the following requirements as to chemical composition:

		Per cent
Combined carbon	Not under	2.50
Graphitic carbon	" over	0.25
Silicon	" "	1.00
Manganese	" "	0.50
Phosphorus	" "	0.25
Sulphur	" "	0.08

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing the spheres into the charge, and unless the analysis conforms to the requirements specified, the batch of spheres shall be rejected.

(9) The scales used shall be placed on a solid level foundation and shall be sufficiently sensitive to determine the initial weight of 10 bricks to the nearest 0.1 pound. The scale shall be tested by a standard test weight at intervals of not more than every ten tests.

(B) Test Specimen

(1) The number of brick per test shall be ten whole bricks for all weights of brick, and the brick shall be weighed to the nearest 0.1 pound. No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

(C) Procedure

(1) (*a*) The sample, together with the abrasive charge shall be placed in the rattler and the rattler closed. The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed ten revolutions will be allowed for starting and stopping. Only one start and stop per test is in general acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the percentage loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

(*b*) Any test, at the expiration of which a staveliner is found detached from the stave or seriously out of position, shall be rejected.

(2) The loss shall be calculated as a percentage of the initial weight of the brick composing the charge, by weighing the brick remaining in the rattler at the end of the test, deducting this weight from the initial weight of the brick, dividing this difference by the original weight of the brick and multiplying by 100.

$$\text{Percentage of loss} = \frac{\text{original weight} - \text{weight after testing}}{\text{original weight}} \times 100.$$

In weighing the rattled brick, any piece weighing less than 1 pound shall be rejected.

NOTE. The percentage of loss to be taken as the standard remains within the province of the contracting parties. For their information, the average percentage of loss after correction as provided in (3) below should not exceed 22% for heavy traffic and 24% for light traffic.

(3) The percentages of loss, as calculated in accordance with paragraph (2) above, shall be corrected by subtracting from it the differential obtained from the following table, which corresponds to the initial weight of the ten brick composing the test charge. The corrected result shall be reported as the corrected percentage of loss.

Weight of 10 bricks before test, lb.	Correction differential (per cent)
95 or over	0
90 to 94 inclusive	1.0
85 to 89 "	1.5
80 to 84 "	2.5
75 to 79 "	3.0
70 to 74 "	3.5
65 to 69 "	4.0
60 to 64 "	5.0
59 or under	6.0

In all cases where the initial weight of 10 bricks in pounds and tenths of a pound lies between the upper limit of one grade and the lower limit of the next heavier grade, the brick shall be classified in the heavier grade when the fractional part of the weight is 0.5 pound or more.

(D) Record

(1) A complete and continuous record shall be kept of the operation of all rattlers working under these tentative methods of testing. This record shall contain the following data concerning each test made:

(1) The name of the person, firm, or corporation furnishing each sample tested.
(2) The name of the maker of the brick represented in each sample tested.
(3) The name of the street or contract, which the sample represented.
(4) The brands or marks upon the bricks by which they were identified.
(5) The number of bricks furnished.
(6) The date on which they were received for test.

(7) The date on which they were tested.
(8) The drying treatment given before testing, if any.
(9) The length, width, and thickness of the bricks.
(10) The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
(11) The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
(12) The total weight of the shot charge, after its last standardization.
(13) Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them to conform to the requirements at the beginning of the test.
(14) Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of staveliners.
(15) The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the counting machine.
(16) Certificate of the operator as to number of stops and starts made in each test.
(17) The initial collective weight of the ten brick composing the charge and their collective weight after rattling.
(18) The loss calculated as a percentage of the initial weight and the calculation itself, the correction factor, and the corrected percentage of loss.
(19) The number of broken bricks and remarks upon the portions which were included in the final weighing.
(20) General remarks upon the test and any irregularities occurring in its execution.
(21) The certificate of the operator that the test was made in accordance with the requirements of the American Society for Testing Materials and that the record is a true record.
(22) The signature of the operator or person responsible for the test.
(23) The location of the laboratory where the test was made and name of the owner.
(24) The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicate, but the original record shall always be preserved intact and complete.

NOTE. For the convenience of those making use of the test, the accompanying blank form, which provides space for the necessary data, is furnished and its use is recommended.

REPORT OF STANDARD RATTLER TEST OF PAVING BRICK

IDENTIFICATION DATA

Name of firm furnishing sample .....
Name of firm manufacturing sample .....
Street or job which sample represents .....
Brands or marks on the brick .....
Quantity furnished ..... Drying treatment .....
Date received ..... Date tested .....
Length ..... Width ..... Thickness .....

STANDARDIZATION DATA

WEIGHT OF CHARGE (After Standardization)	CONDITION OF LOCKNUTS ON STAVES	CONDITION OF SCALES	NUMBER AND POSITION OF FRESH STAVE-LINERS	REPAIRS (Note any repairs affecting the condition of the barrel.)
10 Large spheres				
Small spheres				
Total				

Number of charges tested since last inspection .....

RUNNING DATA

	TIME READINGS			REVOLUTION COUNTER READINGS	RUNNING NOTES, STOPS, ETC.
	HOURS	MINUTES	SECONDS		
Beginning of test.....					
Final reading.....					

WEIGHTS AND CALCULATIONS

	PERCENTAGE LOSS (NOTE.—The calculation must appear.)
Initial weight of ten brick.....	
Final weight of ten brick.....	
Loss in weight.....	
Percentage loss.....	
Correction differential.....	
Corrected percentage of loss.....	

Number of broken brick and remarks on same.....

I certify that the foregoing test was made in accordance with the methods of testing of the American Society for Testing Materials and is a true record.

Signature of Tester.....

Date.....

Location of Laboratory.....

Owner.....

Serial No.....

XIII. PROCEDURE IN REPORTING TESTS

77. REPORT FORM: CHEMICAL ANALYSIS FOR CLAY, FELDSPAR, AND FLINT

Identifying name or number..... .....
Analysis based on material dried at 105°C.....
Ignition loss
SiO_2 (silica)
Al_2O_3 (alumina)
Fe_2O_3 (ferric oxide)
TiO_2 (titania)
P_2O_5 (phos. oxide)
CaO (lime)
MgO (magnesia)
K_2O (potassium oxide)
Na_2O (sodium oxide)

78. REPORT FORM: GENERAL CLAY TEST

(Modified from Form of Bureau of Mines Station, Seattle, Washington)

Identifying name or number
Type of clay — Geological location
Sampled by — Geographic location

Original Properties

Dry Color — Hardness
Visible Impurities
Rate of Slaking — Notes
Mechanical Analysis

Plastic and Dry Properties

Wet color — General plasticity
Temperature and time of drying
Shrinkage water (%) — Pore water (%)
Water of plasticity (%) — Rate of slaking after drying
Dry volume shrinkage (per cent dry volume)
Measured linear shrinkage (per cent dry length)
Dry transverse strength (lbs. per sq. in.)
Drying behavior (cracking, warping, scumming)

Fired Properties

Cone and rate of firing
Color — Hardness
Volume shrinkage (per cent dry volume)
Linear firing shrinkage (per cent dry length)
Linear total shrinkage (per cent dry length)
Per cent absorption
Per cent apparent porosity
Transverse strength (lbs. per sq. in.)
Firing behavior (cracking, warping, scumming)
Pyrometric cone equivalent
Best firing range

79. REPORT FORM: FELDSPAR AND FLINT TESTS

Loss on drying at 105°C
Sieve analysis
Apparent impurities
Pyrometric cone equivalent
Fired appearance (color, specks, etc.)

80. REPORT FORM: TEST OF REFRACTORY CLAY

Received from ..... Date .....
Identification ..... Type of clay .....
P.C.E. (A.S.T.M. Serial Designation C24–20)
Working properties
Water of plasticity
Per cent drying shrinkage (volume)
Drying behavior

DRAW TRIAL DATA

Temperature	Cone	Per cent Porosity	Volume change	Color
1000°C				
1100				
1200				
1250				
1300				
1350				
1400				
1450				
1500				
1550				

Transverse strength after firing to:

Green dried to 110°C — Pounds per square inch. Average of determination.
1000°C
1200
1300
1400
1500

81. REPORT FORM: TEST OF MANUFACTURED REFRACTORIES

Material received from ..... Date .....
Brand ..... Type of material ..... Firing .....
P.C.E. (A.S.T.M. Serial Designation C24–20)
Chemical analysis of sample dried to 110°C. (A.S.T.M. Serial Designation C18–21)

Ignition loss
Silica
Alumina
Ferric oxide
Titania
Lime
Magnesia
Alkalis (combined)

Per cent deformation in load test (A.S.T.M. Serial Designation C16–20)
Per cent linear change resulting in reheating (A.S.T.M. C20–20)

Per cent spalling loss for every 2 treatments (A.S.T.M. C38–21; revised method C38–27T): Average of a minimum of 6 brick
Transverse strength (A.S.T.M. C21–24): Average of a minimum of 6 brick
Per cent porosity
Apparent specific gravity
Coefficient of expansion to 1000°C
Special tests or remarks.

XIV. TEST APPARATUS

(Appendix)

The following descriptions of apparatus are presented without official recognition by the AMERICAN CERAMIC SOCIETY but as means of making readily available, some equipment for conducting important tests on ceramic materials and products. The list is very incomplete but constitutes a nucleus which can be added to as material is presented.

Contributions of detail description and operating procedure of testing equipment should be sent to this Committee and we urge that the outline here followed be made general.

Respectfully submitted,
Arthur S. Watts

A1. HYDRAULIC PLUNGER PISTON-PRESS FOR FORMING CLAY TRIALS

This method of cutting and handling should also be used in making machine-made bars. Figure A1 illustrates a type of hydraulic plunger piston press that is being used successfully for this purpose. In using this press care should be taken in wedging the clay and making it up into a reasonably true cylindrical shape so that it can be placed down into the clay cylinder without trapping it.

A small Mueller or other auger machine fitted with a 30- by 30-mm. die also works very satisfactorily but extreme care should be taken to avoid laminations.

With very plastic and sticky clays a light machine oil does not give relief from sticking to the mold. In such cases a heavy oil or even grease may be found necessary.

It is recommended that the draw trials be marked in sequence for convenience in handling the pieces in testing. Each test piece should have its laboratory number clearly stamped on it and the number of the piece as well. Example, Lab. No. 246, Specimen Nos. 1, 2, 3, etc.

A2. VOLUMETER (Pycnometer Type)

A very satisfactory volumeter of the pycnometer type is described by Schurecht.[1] The author states that the volumes on 30 to 60 test pieces can be calculated per hour.

(1) Operation The bottle is filled with liquid and, as the stopper is inserted, sufficient liquid is forced into the tube in the stopper so that it is filled completely. The excess liquid is carefully wiped off and the bottle is weighed. The briquet to be measured is

[1] *Jour. Amer. Ceram. Soc.*, **1** [8], 556 (1918).

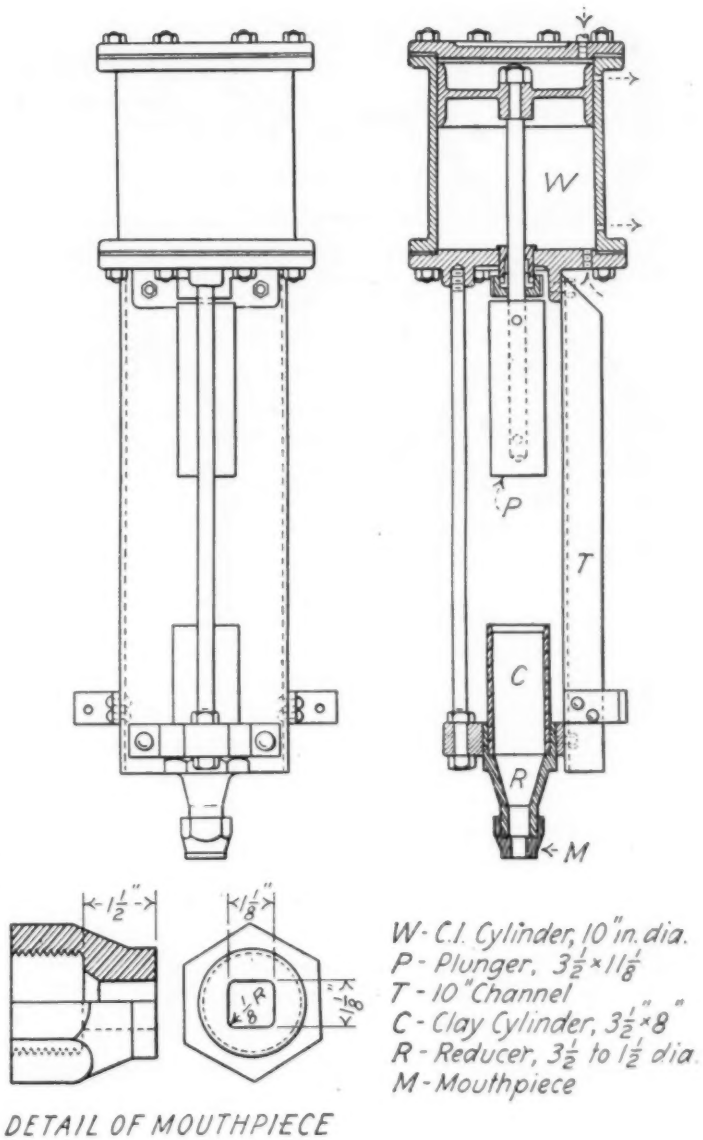

W
P
T
C
R
M
1½"
1⅛"
1R
⅛
1/16
W - C.I. Cylinder, 10" in. dia.
P - Plunger, 3½ × 1⅛
T - 10" Channel
C - Clay Cylinder, 3½" × 8"
R - Reducer, 3½ to 1½ dia.
M - Mouthpiece
DETAIL OF MOUTHPIECE

FIG. A1.

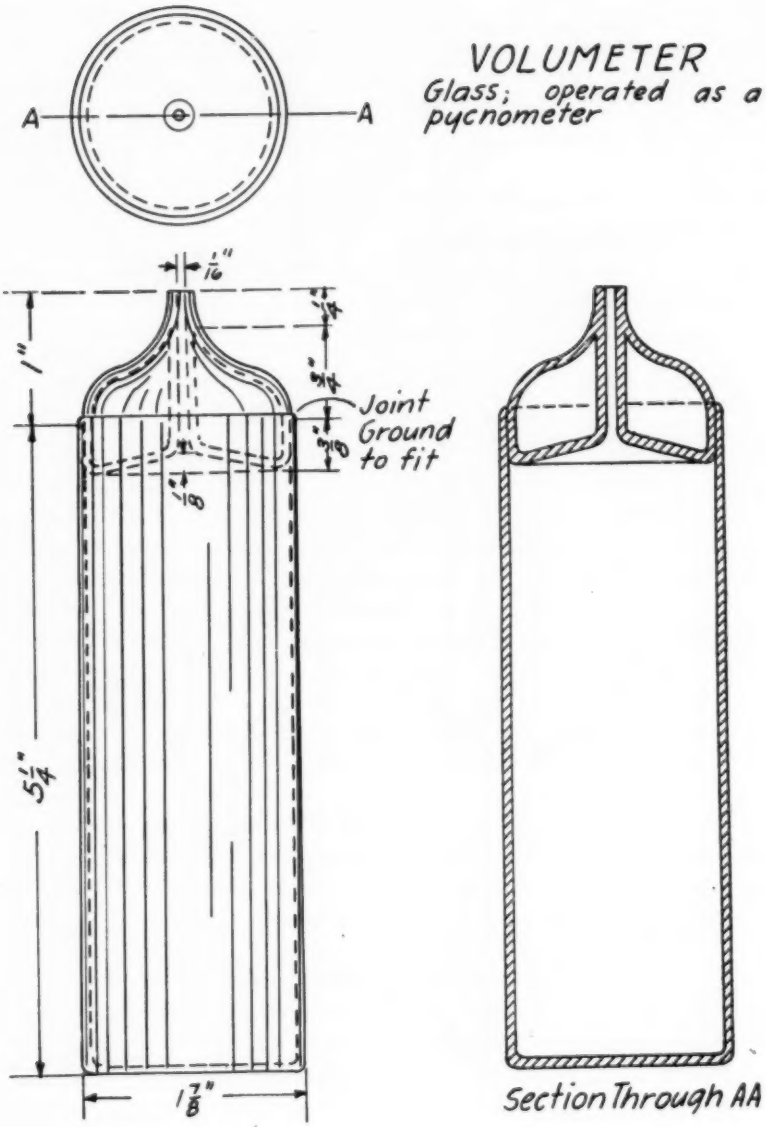

VOLUMETER
Glass; operated as a pycnometer
A
A
1/16"
1"
1/4"
3/4"
Joint Ground to fit
3/8"
1/8"
5 1/4"
1 7/8"
Section Through AA

FIG. A2.

then inserted into the bottle and the operation is repeated. The calculation involved is as follows:

$$V = \frac{W - Wb + B}{S}$$

in which

V = volume
W = weight of bottle plus liquid
Wb = weight of bottle plus liquid plus briquet
B = weight of saturated briquet
S = specific gravity of the briquet

It is necessary to check the weight of the bottle plus the liquid at intervals as minute particles of clay, dropping from the briquets may increase the weight; also on account of the effect of temperature changes upon the oil, if used. This method requires the weighing of the entire apparatus. It also necessitates the determination of the saturated weight. This is difficult to determine accurately on account of enclosed pore spaces and hence does not have the same accuracy as a method where volume is all that is considered.

A3. VOLUMETER (Overflow Type)

The overflow type of direct reading volumeter designed by H. G. Schurecht[1] has been used successfully in many research and control laboratories.

Description of Apparatus Its design and construction are shown in Figs. A3*a* and 3*b*. It consists essentially of a sample container, more than 6 inches high and $2^1/_4$ inches inside diameter and having a small glass tube inserted through the bottom near one side. This tube should extend about 5 inches up into the container if a test specimen 4 by 1 by 1 inches is to be used. The bottom end of the glass tube should extend about 2 inches below the beaker so that it can be inserted into the top of a 100-cc. graduated burette tube.

Operation of Apparatus The sample container should be filled with kerosene (water free) until the liquid overflows through the top of the tube. If a stirrup is to be used to insert the test specimen, this should also be in place empty. All kerosene which has overflowed into the burette should be drained off through the stop-cock into a container. The stop-cock is closed and the test specimen inserted in the container. The kerosene overflows into the

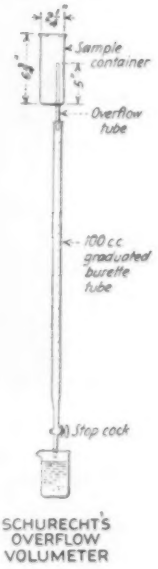


FIG. A3*a*.

[1] *Jour. Amer. Ceram. Soc.*, **3**, 730 (1920).

graduated burette and the volume of the test specimen is read in cc. of kerosene which it displaced and caused to overflow into the graduate.

The test piece is withdrawn, the kerosene is drained from the burette and returned to the sample container, and the apparatus is ready for another test.

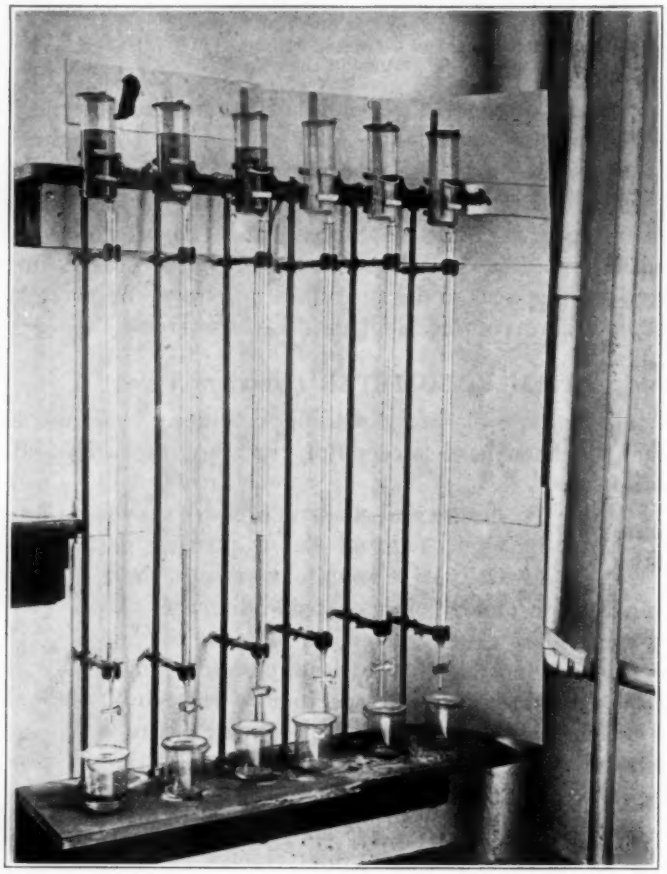


FIG. A3*b*.

Accuracy The only causes for inaccuracy are the variations in meniscus with variation in diameter of sample container

NOTE: Apparatus A4, A5, and A6 may also be employed as volumeters.

A4. POROSIMETERS EMPLOYING LIQUIDS

Apparent Porosity In the standard method for apparent porosity, the test pieces after being saturated by boiling may be cooled by running cold tap water into the pan containing them. Care should be taken, however, to see that the test pieces are continually covered with water.

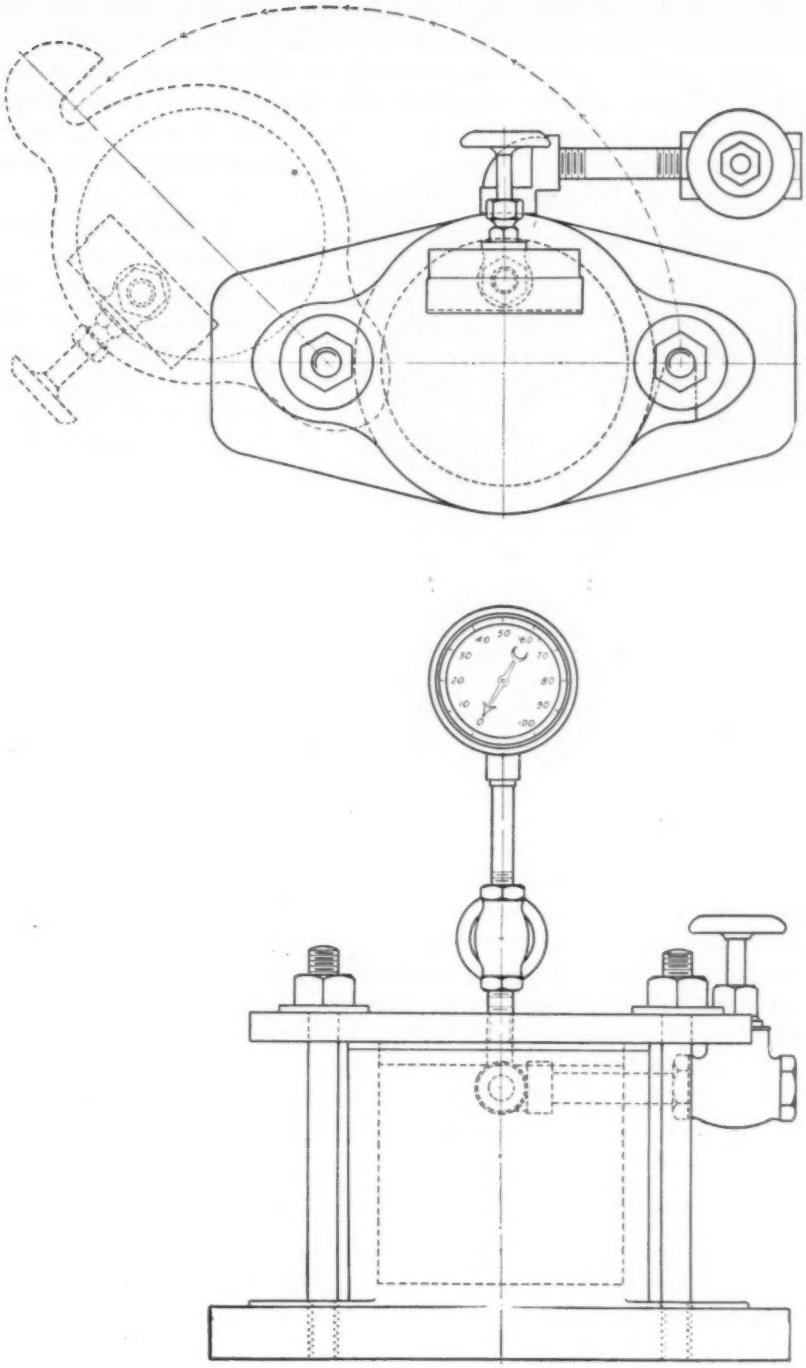


FIG. A4*a*.

More refined methods than the standard are sometimes desirable, as in the case of vitrified porcelains for electrical purposes.

A liquid that penetrates easily should be used for determinations of this sort and it should be colored with some organic color so that the distance of penetration of the liquid into the body can be noted. Ordinary methods of boiling or immersing are not sufficiently severe and pressure has to be used.

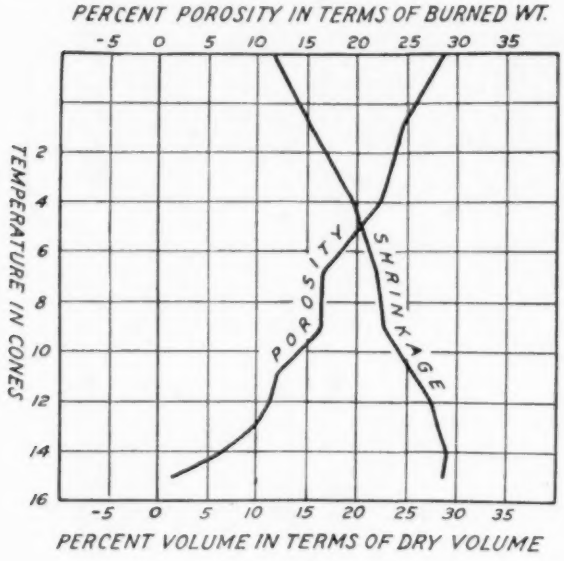


FIG. A4*b*.

The most satisfactory method is to have a strong iron container arranged with a properly bolted cover (Fig. A4*a*). Place the test piece in the container, fill it to overflowing with the colored alcohol so no air will be left in, and then continue to fill the tank by means of a small piston plunger pump properly connected to the container with a valve between. The unit of measure will be the pressure applied. For example, it may be found that for certain purposes it is necessary that there should be no penetration of the alcohol into the porcelain when held at 50 pounds pressure for 15 minutes. It would simply be necessary then to place the test piece in the container, apply the pressure, hold it the necessary time, release, remove the test piece, and break it to see if there has been a penetration. A pressure of at least 80 pounds should be available for this work.

The results should be tabulated in the amount of penetration rather than weight of the liquid absorbed. (See Fig. A4*b*.) (See also Tentative Methods for Testing Electrical Porcelain, Section 73, p. 476 and following.)

A5. POROSIMETER, McLEOD-GAGE TYPE[1]

A metal porosimeter of the McLeod-Gage type has been developed for use in determining the porosity of highly vitrified ware. The

[1] Reprinted from *Jour. Amer. Ceram. Soc.*, **8** [12], 816–21 (1925).

glass capillary is welded directly on to the 20% chrome-steel metal cap. The metal construction gives the rugged apparatus that can be safely handled for routine work. (See Fig. A5*a*.) It is as sensitive as the similar glass apparatus of Washburn and Bunting, but is not structurally delicate. A photograph and drawing with details are included. The suggestion is made that the results obtained by these types of apparatus be expressed as "per cent pore volume," and that the results obtained by water soaking be specifically named "per cent water absorption" to distinguish between them.

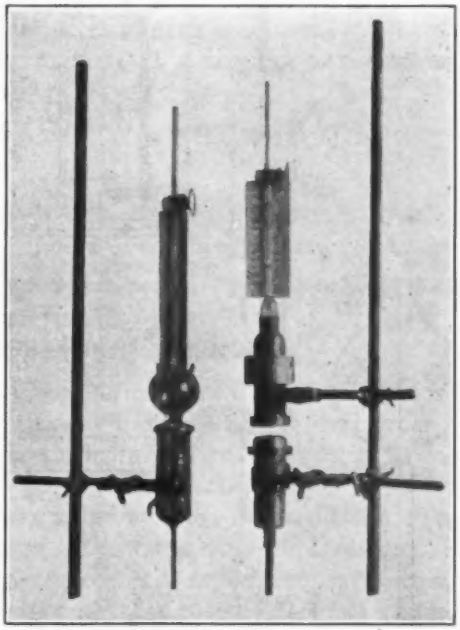


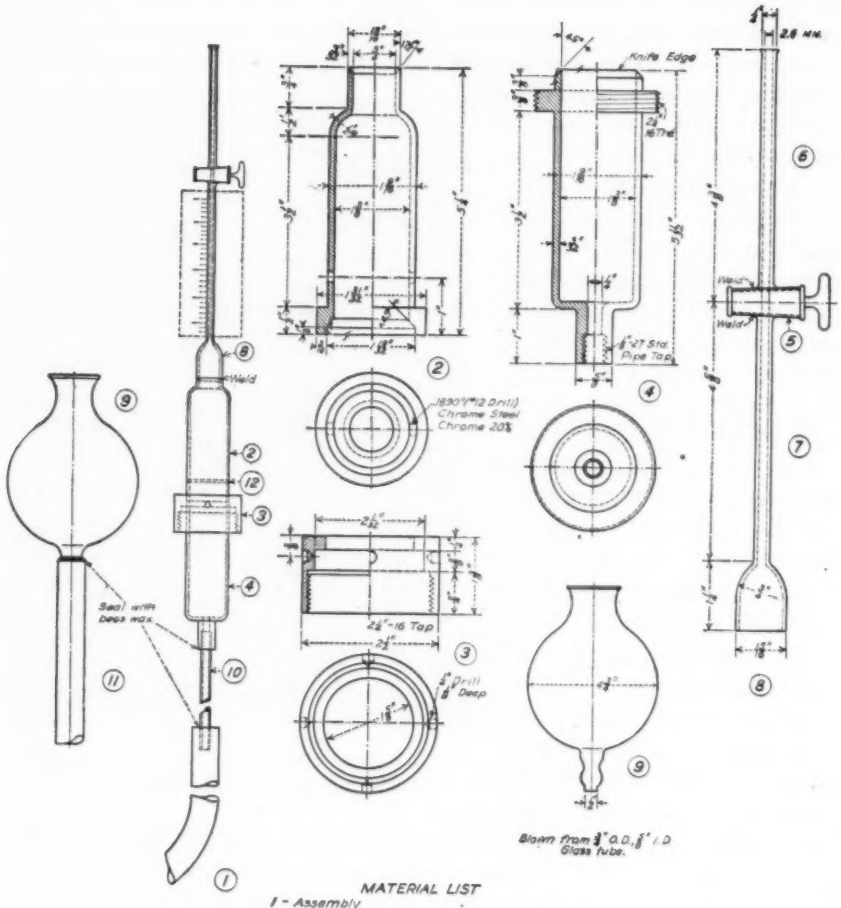
FIG. A5*a*.—Glass and metal porosimeters. McLeod-Gage Type.

Method of Determination

For the sake of completeness, the procedure for testing is included here as incorporated in the Test Methods of the Engineering Laboratory. (See Fig. A5*b*.)

(*a*) After the (fractured) pieces have been assembled in the receptacle of the test instrument and the cap secured in position, the air surrounding the pieces shall be displaced by the mercury by lifting the mercury-leveling bulb. When the mercury level is above the stop-cock, the latter shall be closed. The mercury-leveling bulb shall then be lowered until the lowest surface of the porcelain pieces is entirely exposed. By this means the gas in the porcelain expands in the outer vacuum, and by a subsequent raising of the leveling bulb the gas is accumulated in the capillary. When the level of the mercury in the leveling bulb and in the capillary are at the same height, the gas is at atmospheric pressure and its volume (V_1) shall be read.

(*b*) The stop-cock shall then be opened and the entire procedure of lowering the mercury level below the specimen, removal of surrounding air, expansion of gas into the surrounding vacuum, and accumulation of gas in the capillary, shall be repeated. The second reading of volume (V_2) of gas represents the volume of fine pore space in the specimen.



MATERIAL LIST

1 - Assembly
2 - Cap
3 - Collar (steel)
4 - Receptacle (steel)
5 - Stop Cock 2 MM. hole (glass)
6 - Tube (glass)
7 - Gauge Tube (glass)
8 - Assembly of Stop Cock and Tubes
9 - Mercury Container (glass)
10 - Pipe ⅛", 12" long, one end threaded (seamless steel tube, iron pipe size)
11 - Hose, 1" O.D., ¼" I.D., 5'10" (rubber)
12 - Pin, ⅛" × 2⅞" (steel)

FIG. A5b.

A repetition of the procedure should give a third reading of volume (V_3) similar to the second one. The first value (V_1) is usually too high, since the volume of gas obtained consists of air entrapped on the sides of the porosimeter and held in coarse pockets in the piece of porcelain, and in the fine pores to be measured, and therefore should not be used as a basis for calculation.

(*c*) The total volume (V) of the pieces of each specimen shall be obtained by any suitable volumeter or method, measuring to the nearest 0.2 cc.

(*d*) The pore volume in per cent for each specimen shall be calculated as follows:

$$\text{Per cent pore volume} = \left(\frac{V_2 + V_3}{2}\right)\left(\frac{100}{V}\right)$$

Where V = total volume of test specimen as determined in (*c*).
V_2 and V_3 = the second and third volume determinations of gas as determined in (*b*).

A6. GAS-EXPANSION POROSIMETERS

In an effort to overcome the objections inherent in the liquid absorption method, a number of investigators have devised several types of apparatus which make use of the principle of gas expansion for determining porosity. In this method, a gas instead of a liquid is used to fill the pores of the sample. Bulk volume of the test specimen is determined by direct measurement or by liquid or sand displacement. In the case of highly vitrified ware, it is essential in determining porosity that at least 50% of the surface be newly fractured. This is because a skin is formed which is often more vitreous than the interior of the specimen. The gas-expansion method yields very accurate results even for bodies of low porosity and exceedingly fine pores. The gas-expansion method gives values for porosity which are usually larger than the corresponding values determined by liquid absorption method. The former expresses the actual porosity of the specimen while the latter expresses the absorption. It is desirable that all test specimens be dried at 110°C and allowed to cool in a dessicator before testing.

Of the following porosimeters designed by MacGee,[1] two are suitable for small test specimens and one is suitable for commercial size brick.

Direct Reading Porosimeter

In the apparatus shown in Fig. A6*a*, both the bulk or total and pore volumes of the test specimen are directly read from burettes. This

[1] A. Ernest MacGee, "Several Gas Expansion Porosimeters." *Jour. Amer. Ceram. Soc.*, 9. 814 (1926). Private communication.

apparatus is designed so as to employ test specimens of 1- by 1- by 4-inch dimensions which can later be used in cross-breaking strength or other tests and to give quite reliable porosity values for materials of porosities of 3% or less.

Description of Apparatus D is the sample container of about 150-cc. volume from b to g, the cylinder being about 5 inches long and $1^1/_2$ inches in internal diameter. This container serves also as the expansion chamber. C is a small burette of about 3.5 cc. capacity and calibrated in tenths, the zero being at a. F is a 125 cc. burette calibrated in tenths, the zero being at x. E is a flexible metal-covered rubber tube, the metal covering being essential in order to eliminate errors due to stretching of the rubber.

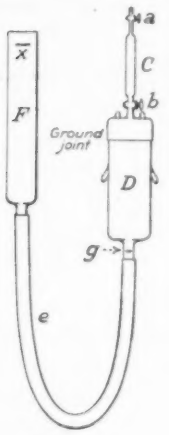


FIG. A6a.

Determination of Porosity Sufficient mercury having been previously placed in the apparatus to fill F to the zero mark when the mercury level stands at g, the test specimen is placed in D and the top securely fastened by means of rubber bands.

(1) With both stop-cocks open, F is elevated until the mercury level is at b.

(2) F is read. This reading subtracted from the previously determined volume of D gives the bulk volume, V, of the test specimen.

(3) F is elevated until the mercury level in C stands at a.

(4) The stop-cock at a is closed and F lowered until the mercury in D stands at about g. By this means the gas in the test specimen expands into the vacuum created and can subsequently be accumulated in the small burette C.

(5) F is elevated until the mercury level in C is at b, when the stop-cock b is closed.

(6) F is lowered until the mercury level in D stands at about g. The gas remaining in the test specimen after the first expansion now expands into the vacuum and can be accumulated in C.

(7) F is elevated and when the mercury level in D is over the test specimen, b is opened.

(8) F is elevated further until the mercury level in C is at the same height as the mercury level in F. Thus the gas in C is at atmospheric pressure.

(9) C is read. This reading is the pore volume, v, of the test specimen.

(10) Porosity in per cent $= \frac{v}{V} \times 100$.

If apparent specific gravity is desired, the solid volume, s, is divided into the dry weight, w, of the test specimen, the quotient being the value sought. Solid volume is obtained by subtracting the pore volume, v, from the bulk volume, V, each being obtained as above described.

Accuracy The precision attainable with this method depends largely upon the refinement of construction of the apparatus. Ten determinations should be made. Values 20% above or below the mean of these values should be discarded. The porosity of the material is taken as the average of the remaining values but should represent at least 60% of the original number of specimens. There is an error due to entrapped air but it is constant for any given apparatus. This constant is determined by using a glass bar of about 1- by 1- by 4-inch dimensions and carrying out a porosity determination as described for a regular test specimen. The reading on C would then be subtracted from all subsequent readings of C, thus making negligible the error due to entrapped air. For porosities of .5% or less, a burette, C, of only 1 cc. volume is desirable. An apparatus of this type is suitable for all classes of ceramic materials, but, of course, the volume of C must be large enough to accommodate all of the gas contained within the test specimen. If a 1- by 1- by 2-inch test specimen were employed, the apparatus herein described would be suitable for porosities as high as 10%.

The Indirect Method

An apparatus was designed to operate on the general principle in which the free-air space is calculated after measuring the fall in pressure which accompanies a definite increase in volume. This type of apparatus was constructed in order that porosity and apparent specific gravity could be accurately and conveniently determined for test pieces of a wide range in size and shape and porosity. This apparatus was designed to carry a test piece 1 by 1 by 4 inches, a convenient size to make and a size which readily lends itself to other tests, including cross-breaking strength on a 3-inch span.

Description of Apparatus Figure A6*b* is a diagrammatic sketch of the indirect reading porosimeter. A is the sample container of any convenient volume up to the make, K. In this particular apparatus, the volume of A is 145 cc., the cylinder being about 5 inches long and $1^1/_2$ inches in diameter. This is a convenient size for carrying 1- by 1- by 4-inch test pieces and at the same time allowing for considerable oversize. B is an expansion bulb of any convenient volume from K to L. With a sample container of the volume mentioned above, about 50 cc. is the proper volume of B in order to assure accuracy when a great variety of sizes in test pieces is likely to be encountered. C is a regular 200-cc. burette calibrated into tenths. D is an ordinary meter

stick. The open-end manometer, x and y, is made of about 5 millimeter bore tubing. Beginning at a point just below K, the open end of x is made of fine capillary tube. This is in order to avoid the use of a second stop-cock and at the same time to retain accuracy in the bulk volume measurement (as A is being filled with mercury, some would be running out of C into this manometer tube, thus making the reading on C too large). E is a metal covered rubber tube, metal being used to avoid stretching by the mercury employed in the apparatus.

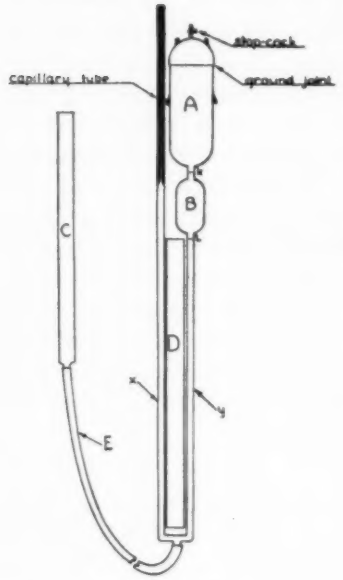


FIG. A6*b*.

Determining Porosity Sufficient mercury having previously been placed in the apparatus to fill C to the zero mark when the mercury level stands at K, the sample is placed in A and the top fastened securely by means of rubber bands.

(1) With the stop-cock open, C is elevated until the mercury level in B stands at K.

(2) After closing the stop-cock, C is lowered until the mercury in B stands at L.

(3) The pressure difference between x and y is read on D. The solid volume is calculated from this reading.

(4) After opening the stop-cock, C is elevated until the mercury level in A stands at the stop-cock.

(5) C is read. This reading subtracted from the total volume of A gives the bulk volume, v, of the test piece.

Calculating Solid Volume (1) The reading, R, of D (as determined under (3) above) is subtracted from the barometric pressure in order to obtain the pressure, p, after the expansion process described under (1) and (2) above.

(2) Air space, a, in $A = \dfrac{p \times B}{R}$

B is the volume from K to L

(3) Solid volume, s, of test piece $= A - a$

A is the volume from the stop-cock to K

(4) Porosity in per cent $= \dfrac{v - s}{v} \times 100$

Advantages If apparent specific gravity is desired, it is determined by dividing the solid volume into the dry weight, *w*, of the test piece.

This apparatus is rugged and simple in its construction. It gives quite accurate values for all classes of ceramic bodies other than those of porosities less than 10%. Where many tests are being made, the mercury soon becomes dirty unless exceptional care is used to clean the test pieces before using. This apparatus is relatively insensitive to the small amount of dirt which gradually accumulates in any apparatus of this general type. Although this apparatus does not have the advantage of the direct reading feature, it is quite rapid and convenient in its operation.

Accuracy The accuracy attainable with this apparatus is all that can be necessary except for ware of the lowest porosities. For great accuracy, it is essential that the rubber tube does not stretch. This is assured by having it inclosed in a snugly fitting flexible metal tube. Ten determinations should be made. Values 20% above or below the mean of these values should be discarded. The porosity of the material is taken as the average of the remaining values but should represent at least 60% of the original number of test specimens. This apparatus operates at about $^1/_4$ atmosphere. If greater accuracy is desired, it is only necessary to increase the volume of *B*.

Indirect Reading Brick Porosimeter

Apparatus The sample container is made of $^1/_4$-inch rolled steel plate with inside dimensions slightly larger than the standard dimensions of refractory brick. A cover plate made of steel plate is clamped in place by means of eight wing nut bolts and made air tight by a soft rubber gasket. The sample container covers, however, could be ground to fit and made air tight by means of heavy stop-cock grease. Although a glass leveling bulb is used on the apparatus herein pictured, a metal leveling bulb could be used quite advantageously. The expansion bulb, manometer, and connections are made of glass. As these are fixed permanently and in no danger of being broken, glass is at no disadvantage. An ordinary heavy-walled rubber tube is used to connect the leveling bulb to the manometer.

Figure A6*c* is a diagrammatic sketch of this apparatus. *A* is the brick container of about 2000 cc. volume. The expansion bulb, *B*, is made of glass and has a capacity of about 250 cc. *C* is a leveling bulb. *D* is an ordinary meter stick. The manometer, *x* and *y*, is made of glass tubing of about 5 millimeters internal diameter. Ordinary heavy-walled rubber tubing, *w*, is used and is not reinforced by a metallic covering as explained in the case of the other apparatus. *A* is connected to *B* by means of the capillary glass tube, *z*.

Operation Sufficient mercury having been previously placed in the leveling bulb to fill B up to the mark, K, the brick is placed in the sample container, A, and the cover put in place.

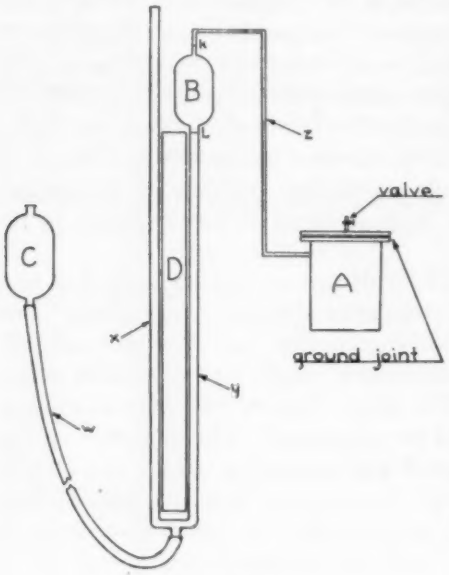


FIG. A6c.

(1) C is elevated until the mercury level in B stands at K after which the stop-cock is closed.

(2) C is now lowered until the mercury level stands at L.

(3) The pressure difference in x and y is read on D. From this pressure difference the solid volume of the brick is calculated.

Calculation of Solid Volume (1) The reading, R of D (as determined under (3) above) is subtracted from the barometric pressure in order to obtain the pressure, p, after the expansion process described under (1) and (2) above.

(2) Air space a, in $A = \dfrac{p \times B}{R}$

B is the volume from K to L

(3) Solid volume, s, of test piece $= A - a$
A is the volume of the sample container

(4) Porosity in per cent $= \dfrac{v - s}{v} \times 100$

The bulk volume, v, of the brick is determined by direct measurement with a meter stick, the average of several readings in each dimension being taken.

If apparent specific gravity is desired, it is determined by dividing the solid volume into the dry weight, w, of the brick.

Accuracy The accuracy attainable with this apparatus and method is well within the limits ordinarily required in routine factory control, research, and development work. Ten determinations should be made. Values 20% above or below the mean of these values should be discarded. The porosity of the material is taken as the average of the remaining values, but should represent at least 60% of the original number of test specimens. This apparatus operates at about $^1/_4$ atmosphere. If greater accuracy is desired it is only necessary to increase the volume of B.

References

E. W. Washburn and E. N. Bunting, "Porosity VI. Determination of Porosity by the Method of Gas Expansion," *Jour. Amer. Ceram. Soc.*, **5**, 112 (1922); "Porosity VII. The Determination of the Porosity of Highly Vitrified Bodies," *Jour. Amer. Ceram. Soc.*, **5**, 527 (1922).

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E. E. Pressler, "A Simple Brick Porosimeter," *Jour. Amer. Ceram. Soc.*, **7**, 154 (1924).

M. L. Hartmann, O. B. Westmont, and S. F. Morgan, "The Determination of the Bulk and Pore Volumes of Refractory Materials," *Jour. Amer. Ceram. Soc.*, **9** [5], 298–310 (1926).

E. E. Pressler, "Comparative Tests of Porosity and Specific Gravity on Different Types of Refractory Brick," *Jour. Amer. Ceram. Soc.*, **7** [6], 447–51 (1924).

A7. LOAD TEST FURNACE AND EQUIPMENT

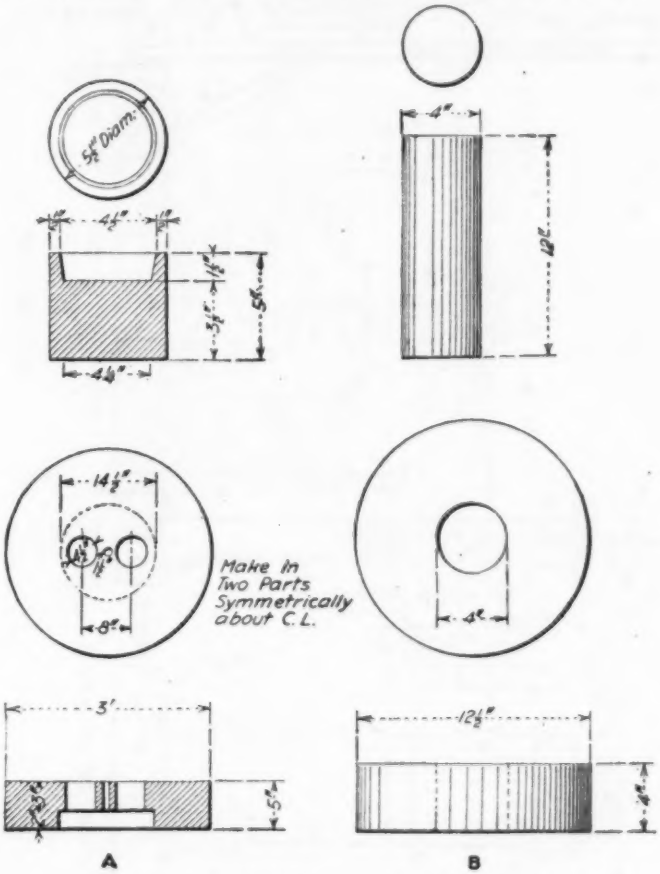


FIG. A7*a*.—Special shapes required for furnace.[1]

[1] Courtesy of *Metallurgical and Chemical Engineering*.

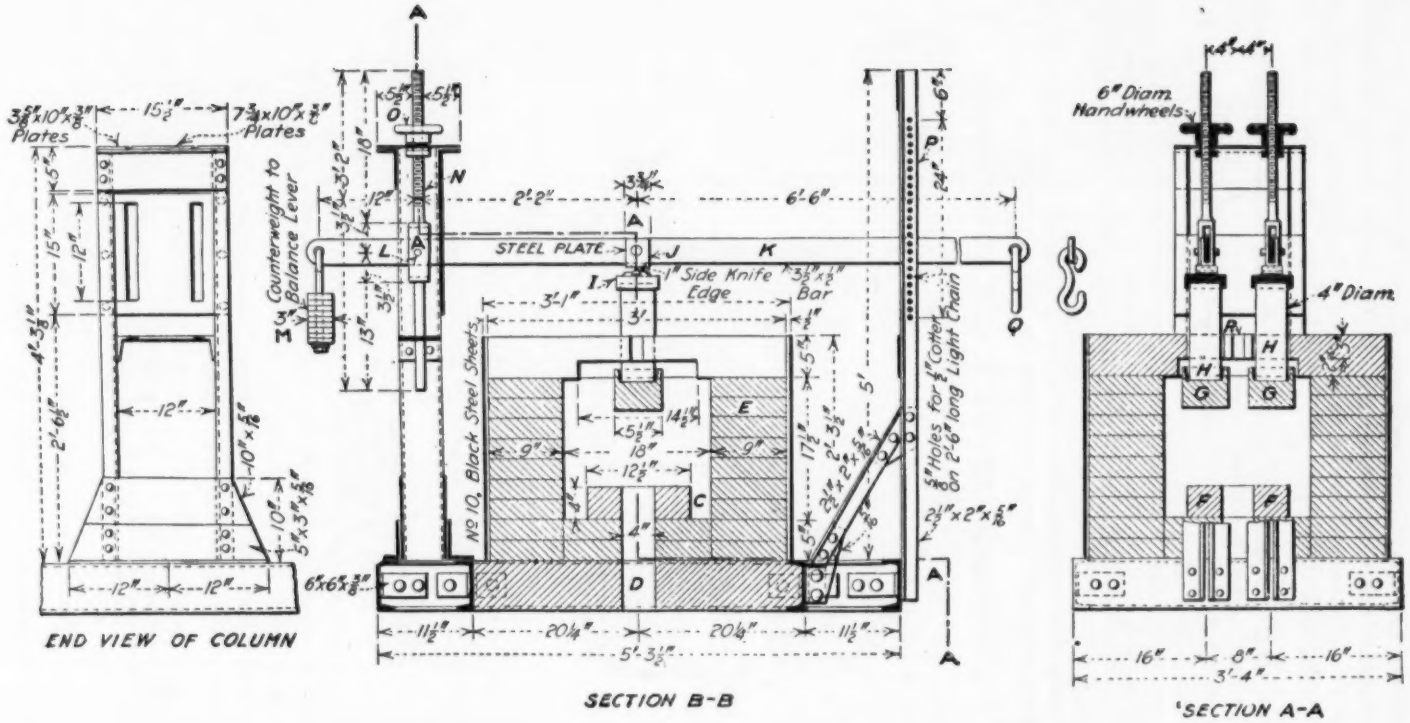


FIG. A7*b*.—Apparatus for testing refractory materials under load at high temperatures.[1]

[1] By courtesy of *Metallurgical and Chemical Engineering*.

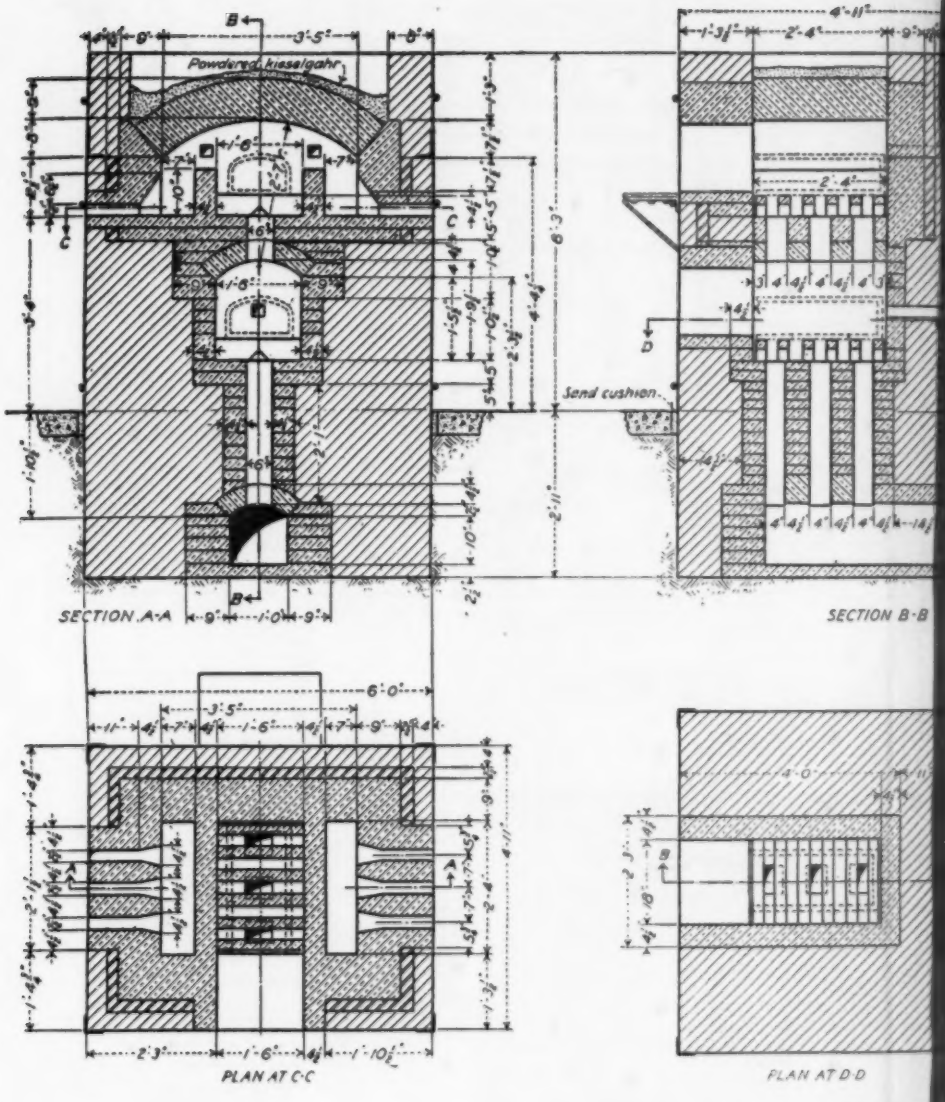
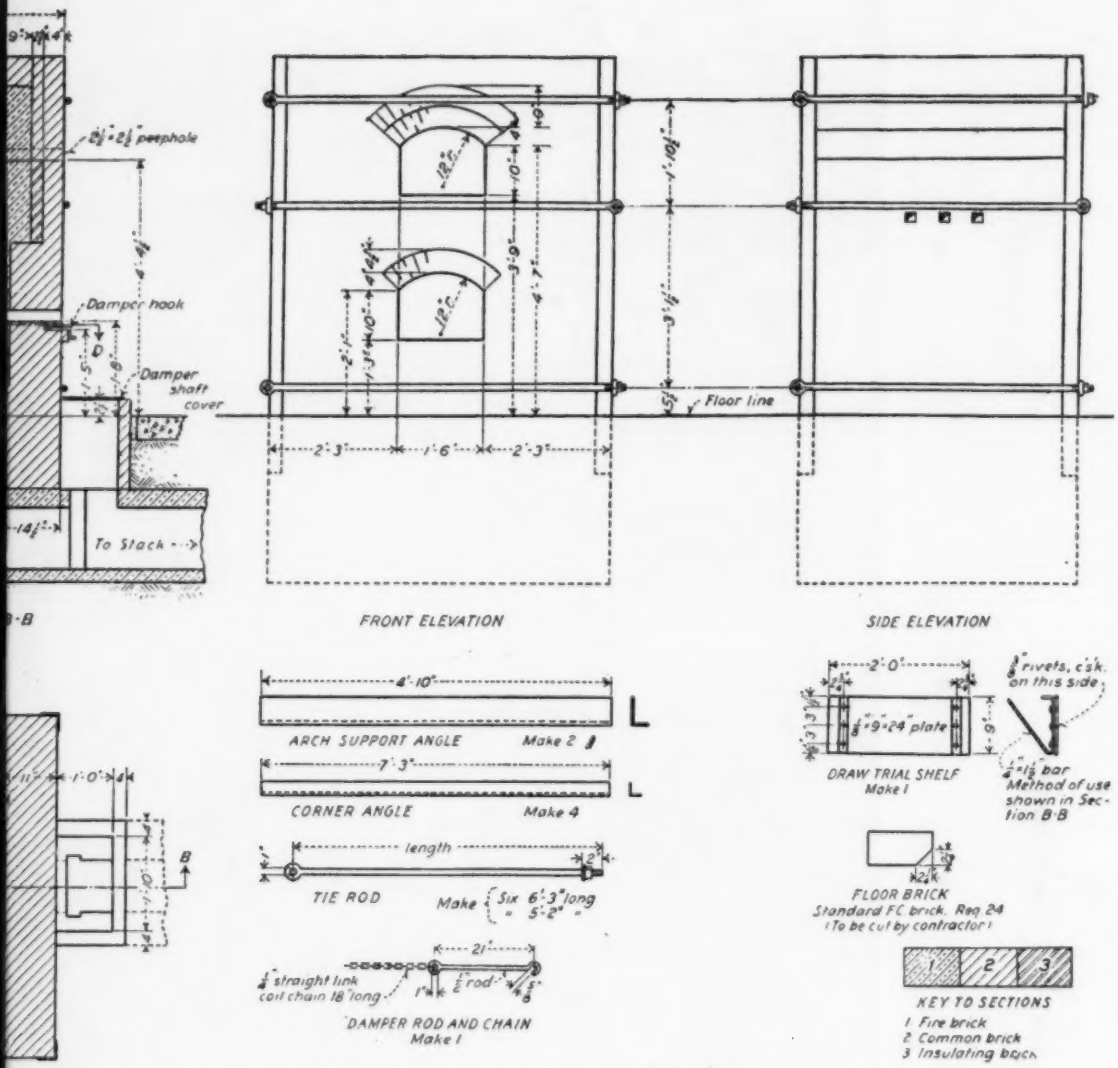

Powdered kissalgahr
Sand cushion
SECTION A·A
SECTION B·B
PLAN AT C·C
PLAN AT D·D

FIG. A8.-



Note This kiln is designed for muffle 13½" × 9" × 26½" outside

8.—Kilns and their operation.

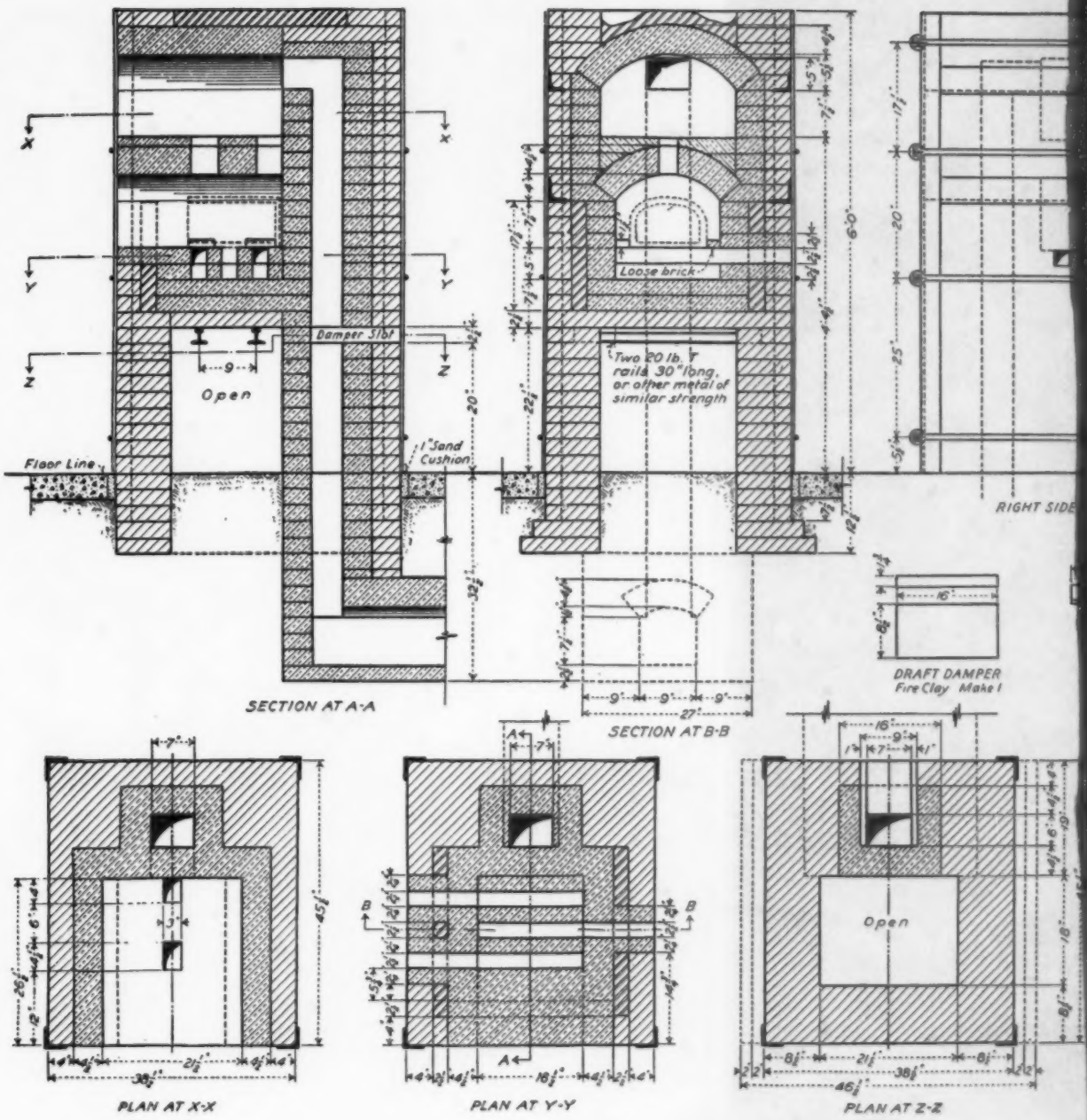
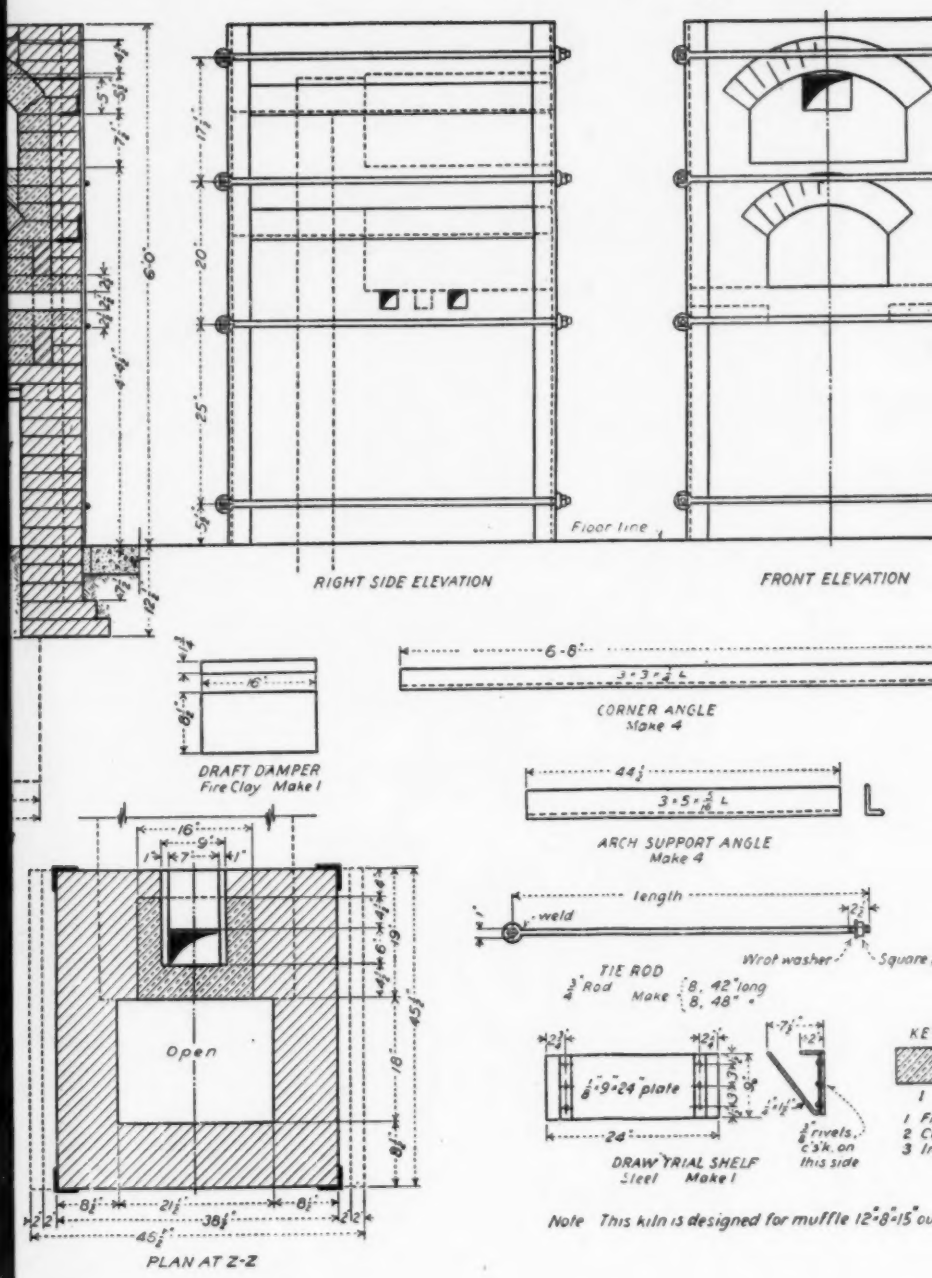
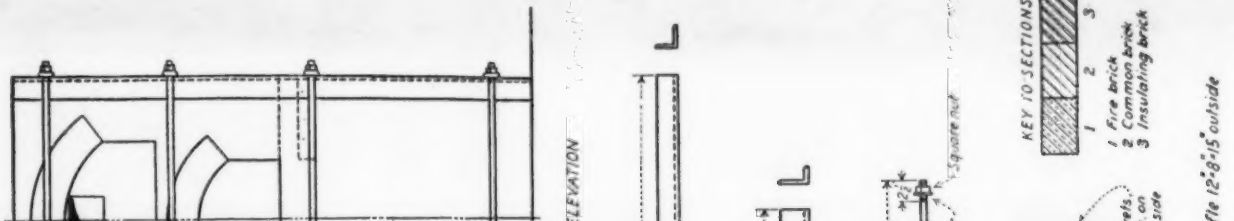


FIG. A9.—Kilns and their operation.



9.—Kilns and their operation.

A9. UPDRAFT TEST KILN



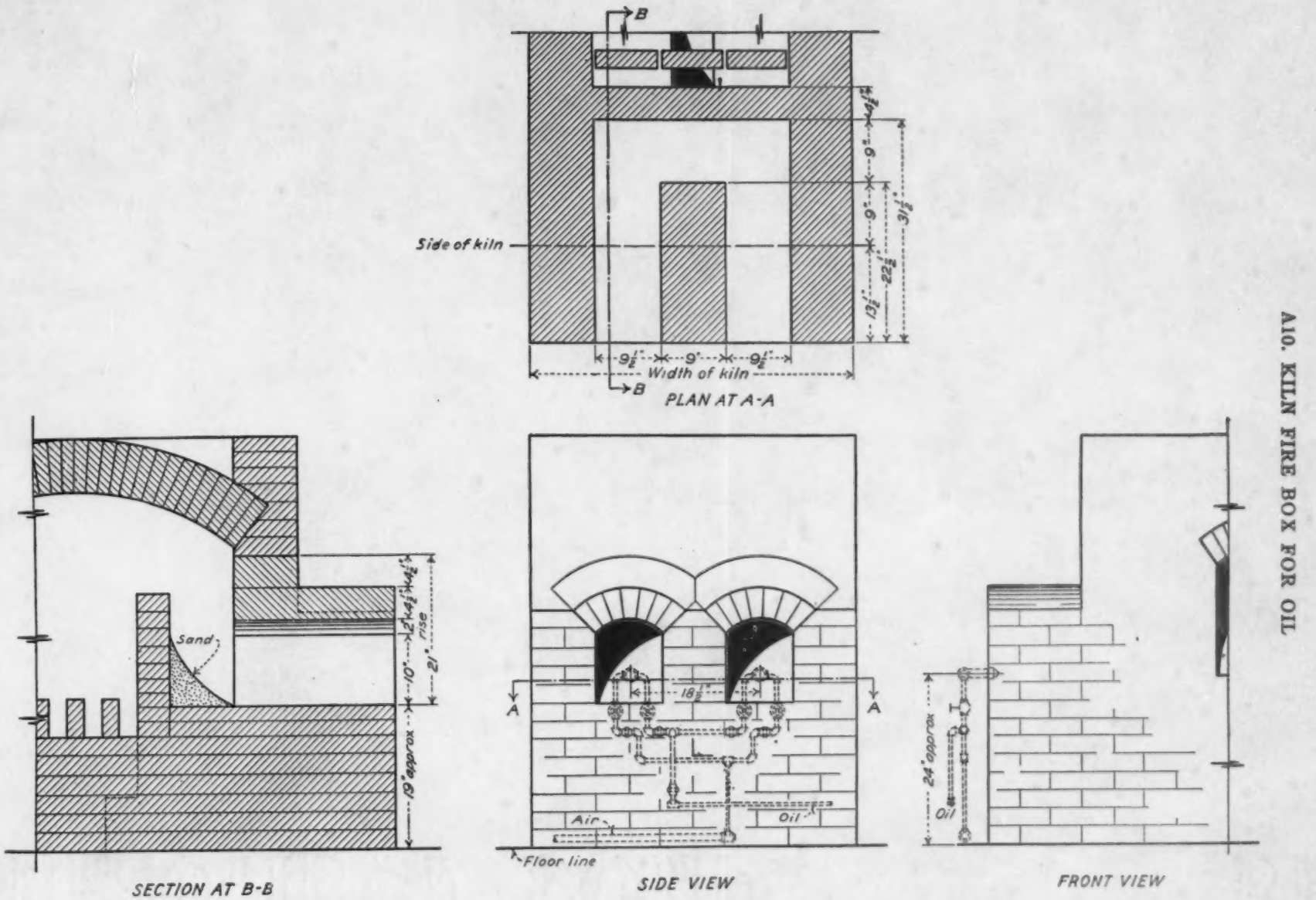


FIG. A10.—Kilns and their operation.

A11. AR

A11. ARRANGEMENT OF CONES, TEST PIECES, ETC., IN KILN

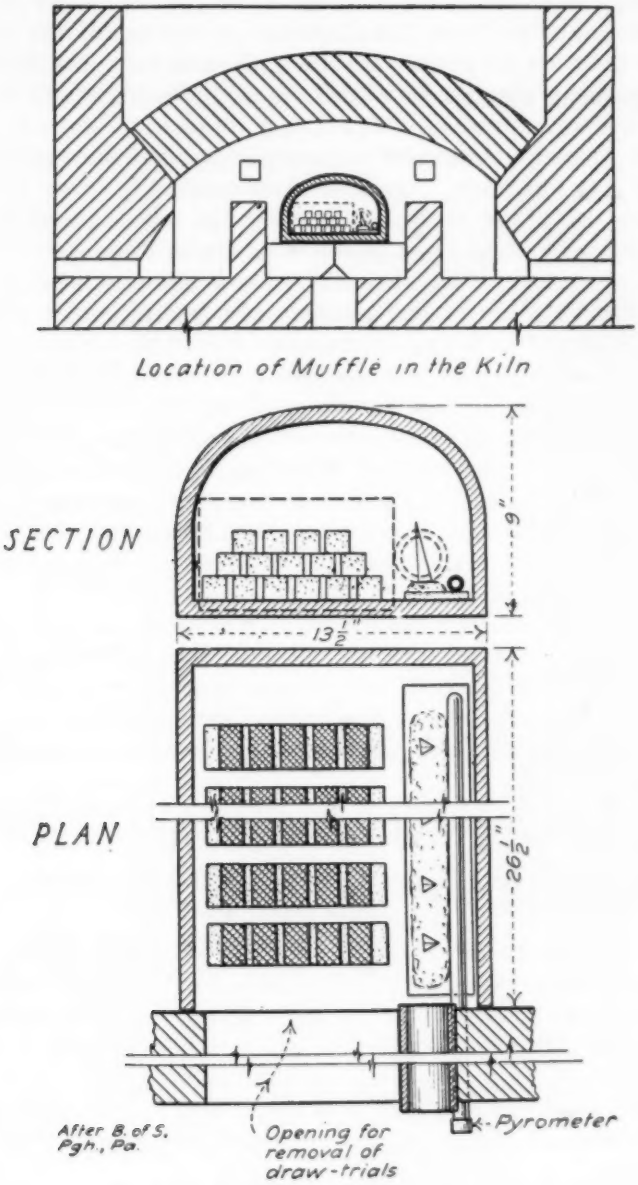


FIG. A11.—Kilns and their operation.

A8, A9, A10, A11. KILNS AND THEIR OPERATION

Figures A8 and A9 illustrate two types of kilns for use in making draw trial firings. Any small kilns in which muffles can be placed are satisfactory but they do not have the advantage of the annealing muffle, height for the convenient draw of trials, etc. The kilns shown are designed for gas and air. To burn oil, it would require additional oil box space as shown in Fig. A10 while coal would require considerable alteration, not only of fire boxes but also flue openings.

Figure A11 illustrates a suitable arrangement of cones, test pieces, and pyrometer in the muffle. This, of course, can be varied somewhat as long as the cones and test pieces to be drawn at the softening point of the cones are close together. The figure shows a cone directly in line with each group of test pieces. The test pieces in each group are drawn at the softening of the cone in line with them. The hot junction of the thermocouple can also be very close to this point if the couple is drawn out of the kiln until the hot end is opposite the trials to be drawn and pushed into the kiln as required. The illustration shows 15 different stacks of test pieces arranged for drawing. In work of this sort care should be taken in knowing something about the range of each body or clay before placing the kiln as it is possible to have one test piece overfire and soften or even melt and spoil several others in the same group.

If the test pieces are properly marked in sequence for each laboratory number they should be placed in the muffle with No. 1 piece for the first draw, No. 2 for second, etc. This makes it easy to sort the pieces as well as to avoid hopeless mixing in placing the pieces in the annealing muffle, unless undue care is exercised in drawing and placing in the annealing muffle.

A12. PENDULUM TYPE OF IMPACT TESTING MACHINE

Adaptation of Charpy Type of Impact Testing Machine to Ceramic Materials[1]

After a survey of the types and examples of impact machines briefly described above, the writer has considered the Charpy machine of the Bell Telephone Company as the most desirable. Free use has been made of their drawings kindly put at the writer's disposal. One important feature not included in their instrument is the variable support for different-size specimens found of great value with ceramic materials. A photograph of the apparatus illustrates the general construction. (Fig. A12.)

The pendulum consists of an aluminum framework swinging in ball-

[1] Reprinted from, L. Navias, *Jour. Amer. Ceram. Soc.*, 10 [2], 90–97 (1927).

bearing supports, carrying a hardened steel striking bob. The length of the pendulum from central support to the center of the striking edge of the bob is thirteen inches. The effective weight of the bob at the center of the striking edge is exactly one pound. The bob is allowed to fall from a height of two feet, measuring from the center of the striking edge of the bob to the horizontal plane through the center of the specimen. The applied energy is 2 ft.-lbs. and the velocity of impact 11.3 feet per second. The pendulum carries an arm which is rigidly held parallel to it, and when the pendulum reaches a vertical position, that is, when it makes contact with the specimen, the secondary arm engages an aluminum pointer which is carried to the highest point reached by the pendulum. The pointer has a light spring attached which enables it to remain in any position without falling back.

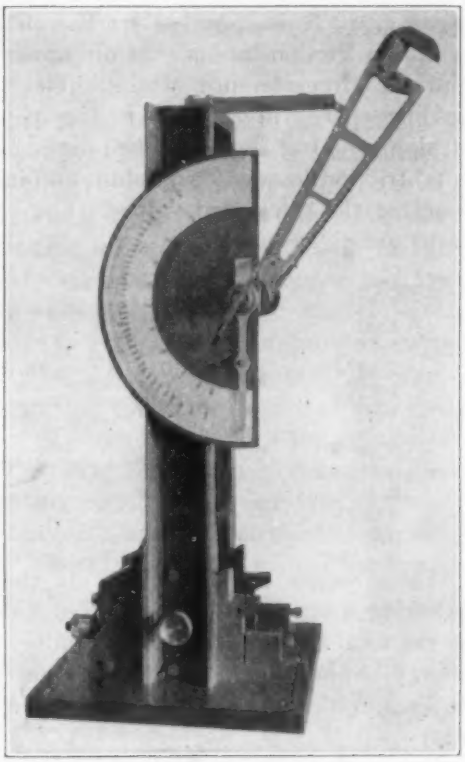


FIG. A12.—Pendulum type impact testing machine.

Scale The scale is made from a working drawing of a semicircle with thirteen-inch radius, the center corresponding to the center of the pendulum support and the diameter placed in a vertical direction. Horizontal parallel lines, spaced $^1/_{100}$ foot apart are drawn across the diameter to meet the circumference. Radial lines drawn from these intersections give a circular scale as illustrated, the radius of the scale being in this case six inches. Each division on the scale is equivalent to .01 ft.-lb., but the divisions are of unequal width, being more crowded near the middle of the scale. These values are theoretical, and correspond to those attained by a frictionless pendulum.

Friction Corrections In reality the pendulum absorbs a small amount of energy amounting to 0.035 ft.-lb. for an entire swing (about 296°). At the point of impact, the pendulum

has absorbed (in friction) just half of the friction energy, namely, 0.0175 ft.-lb. As the pendulum friction is proportional to the linear drop of the pendulum, the friction between 0.0 and 2.00 ft.-lb. may be equivalently proportioned between .0175 and 0.035 ft.-lb. giving a straight line relationship. The friction in the indicator starts at zero at the time of impact and mounts to .020 ft.-lb. for a 2.00 ft.-lbs. drop. The indicator friction depends upon an angular relationship and was found by subdividing the arc of circle of the working diagram into an equal number of parts and assigning equivalent values to each angular sector (.020 ft.-lb. per 148°). The height of fall responsible for each indicator friction loss is read off at the intersection of the radial lines and the circumference of the circle. On plotting indicator friction against energy in the bob in foot-pounds, the relationship is not a straight line but shows marked divergence for low friction losses. The total friction losses of pendulum and indicator are obtained by adding together the calculated values. The values for this particular instrument are given below:

Drop (ft.-lbs.)	Friction in pendulum bob (ft.-lbs.)	Friction in indicator (ft.-lbs.)	Total friction loss (ft.-lbs.)
2.00	.035	.020	.055
1.75	.033	.017	.050
1.50	.031	.015	.046
1.25	.028	.014	.042
1.00	.026	.012	.038
0.75	.024	.010	.034
0.50	.022	.008	.030
0.25	.020	.006	.026
0.125	.019	.004	.023
0.0625	.018	.003	.021
0.0	.017	.0	.017

These values have been put on the scale for convenience. After breaking a specimen the indicated value of residual energy is added to the total friction loss for that value, the sum being the true residual energy, which when subtracted from the initial applied energy (2.0 ft.-lbs.), gives the actual energy consumed in breaking the specimen.

Before a run the pendulum is allowed to swing free, and the value attained should be 1.945 ft.-lb., giving .005 ft.-lb. for the total friction loss. Of the two components making up the friction loss the one liable to vary is that of the indicator due to a slight tightening of the spring after continued use. It has been found convenient to maintain one set of friction loss data and reset the spring to maintain these values.

Specimen Supports (for Any Size Test Specimen between $^1/_2$ and $1^1/_8$ Inches) The specimen is carried by two hardened metal L's shaped out of metal blocks which ride between parallel supports. The upper support is firmly and perma-

nently fixed to the framework, while the lower support in the shape of a triangular wedge may be freed by loosening the screw pressing against it. (Square head-screw seen at right of photograph, Fig. A12). The specimen support is moved by actuating a micrometer screw (divided in $^1/_{1000}$-inch divisions) shown at the left of the apparatus. A large knurled-head screw at the side of the supports when turned causes the specimen support to be drawn and held tightly against the uprights. For a readjustment of the specimen supports it is necessary to loosen the wedge screw slightly and loosen the knurled-head screw.

After adjustment of position of specimen by means of the micrometer screw, the wedge is tightened as well as the side screw. The supports are extremely rigid.

Each specimen support is constrained to move in a path at an angle of 26°34′ from the horizontal, which causes it to move simultaneously twice as far horizontally as vertically. Hence when a specimen with either square or round cross-section is in position for impact it will be found when the hammer is hanging down freely (indicator at zero), that the specimen is centrally located between the upper and lower (interior) sides of the pendulum hammer and that the central point of the striking edge of the hammer is in vertical alignment and in contact with the outer edge of the specimen.

Dimensions of Supports and Striking Edge

Both arms of each L are rounded to a curvature of $^1/_8$-inch radius with the arms of the L, 90° apart. The span between points of contact is four inches. The striking edge of the pendulum hammer is rounded to a curvature of $^1/_8$-inch radius, and the two sides of the wedge forming the striking edge are 45° apart. Specimens with either circular or square cross-sections can be accommodated.

A13. A "SEALED-IN MERCURY ELECTRODE" APPARATUS FOR TESTING BREAKDOWN VOLTAGE OF HEAVY INSULATING MATERIALS[1]

Of several modifications of the apparatus the type here depicted has been the most successful (Fig. A13). Essentially the apparatus consists of two hollow electrode supports, one a glass or metal elbow, the other a straight 6-inch length of glass tubing.[2] The elbow is held in a simple wooden frame. Originally the elbow was made of quartz glass but it has been found that Pyrex glass is just as suitable and much less expensive.

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[1] L. Navias, *Jour. Amer. Ceram. Soc.*, **9** [9], 598–605 (1926).

[2] The inclined tube is either glass or metal. Sealing wax is used underneath the specimen as well as above it.

The metal elbow is made of three parts of ordinary plumbers' cast-iron stock, a length of pipe bent at an angle of 45°, an elbow and a short length whose upper surface has been machined flat. The glass parts have had their rims fire-flashed. Of the various common metals which could be used for the metal elbow it was found that cast-iron has a similar specific resistance to mercury, namely: mercury 94, cast-iron 98, while commercial iron is 9–12, soft steel 16, and hard steel 46.

Sealing Specimen between Electrode Supports

The specimen to be tested is sealed between the two parts with ordinary red sealing wax. An efficaceous method is to invert the elbow, supporting the framework on a protruding board. A molten mass of wax is brought in contact with the rim of the tube, and by a succession of dips any thickness can be obtained. The specimen is then immediately brought in contact with the wax and after a short period of time the specimen will be held rigidly in place. The upper glass tube is then cemented to the specimen in a similar manner. Mercury is poured into the elbow, and the air entrapped is easily displaced by tipping the apparatus. In the glass elbow it is plainly seen how effective this simple process is in obtaining good contact between the specimen and the mercury. Mercury is also poured into the upright tube. Lead wires put in contact with the two mercury arms of the apparatus complete the circuit. In place of a long glass arm or a long pipe for the inclined electrode, it has been found feasible to use only a short rigid inclined portion with a rubber hose of large diameter attached.

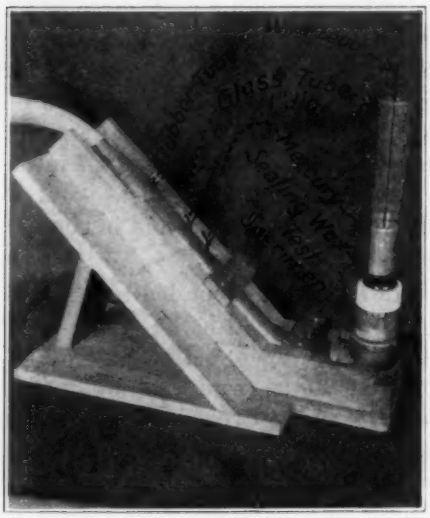

FIG. A13.

Puncturing under Oil

For the actual test the whole apparatus is immersed in a bath of oil with the upper ends of the electrode supports protruding. The lead wires are thus maintained quite far apart. The voltage may now be applied and increased until the specimen is punctured, the path of the puncture being confined to the area inside the tubes. The metal elbow has a great advantage over those

made of glass or silica glass, for after three or four puncture tests the glass elbows are found to crack below the specimen and near the right-angled bend. Whether this is due to the localized heating or mechanical shock has not been ascertained. The metal elbow after scores of punctures shows no signs of deterioration. The upright glass electrode support is not subject to the cracking.

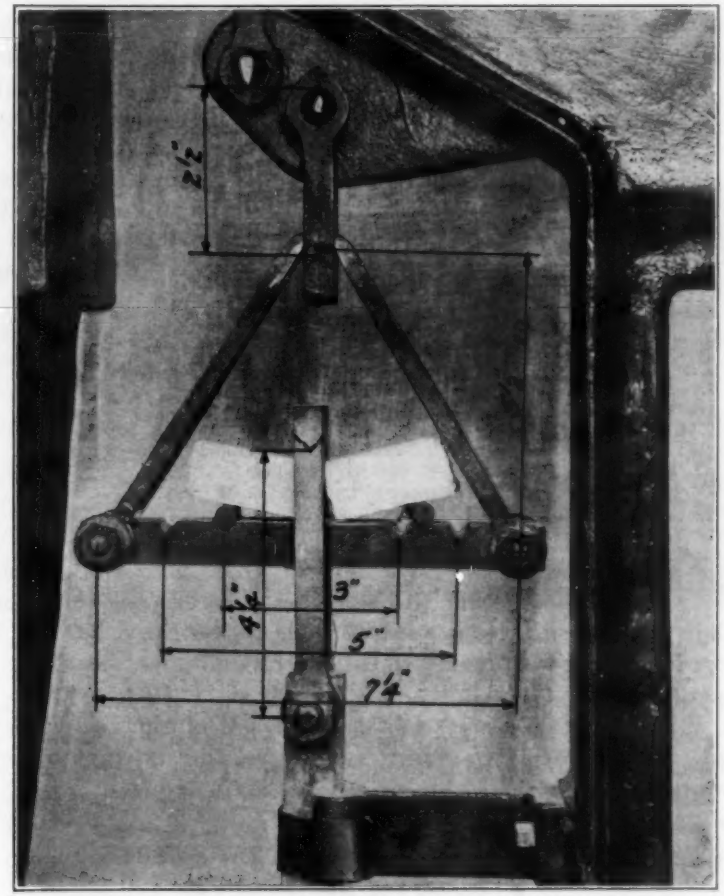

FIG. A14.—Cross-breaking machine.

A14. CROSS-BREAKING (TRANSVERSE STRENGTH) APPARATUS

A standard Riehle tensile strength machine equipped with an especially designed stirrup is employed.

Determination of Cross-Breaking (Transverse) Strength The test specimen of approximately one square inch cross-section is placed on the supporting cylindrical bearings, which are either 3 or 5 inches apart as provided in the stirrup construction. The upper bearing or knife edge is lowered by means of the hand-screw wheel to make contact with the center of the test specimen. (Badly warped test pieces prevent equal distribution of load and should be discarded). The lever arm of the machine is drawn to a horizontal position by means of the hand crank connected with the hand screw and must be maintained level throughout the test by turning this hand crank. The load is applied by releasing the shot contained in the receptacle at the other end of the lever arm. When the test specimen breaks, the flow of shot automatically ceases, and the breaking load is indicated by the weight of shot which has flowed out into the scale pan.

Calculation Cross-breaking strength expressed in terms of modulus of rupture:

$$M = {}^3/_2 \frac{(P \cdot l)}{(bd^2)}$$

in which

M = modulus of rupture in lbs. per square inch
P = load in pounds indicated on scale which weighs shot
l = span in inches over which test piece is broken
b = breadth of test piece in inches
d = depth of test piece in inches

Accuracy The accuracy of this data depends on the uniformity of structure of the test specimens and on freedom from irregularity of the surfaces in contact with the bearings, but the latter is most important with regard to the central and upper bearing.

Usually ten test specimens are employed, and any values more than 20% higher or lower than the average of the ten values obtained, are discarded. If the accepted values do not constitute 60% or more of the total tests, the entire series is condemned.

A15. ELASTICITY AND TRANSVERSE STRENGTH APPARATUS

Figures A15*a* and A15*b* show an apparatus designed by A. Ernest MacGee[1] for determining transverse strength and elasticity for unfired as well as fired test pieces. Figure A15*b* shows a diagrammatic sketch of this apparatus which is designed to break an inch square test piece over either a 3-, 5-, or 7-inch span.

[1] *Jour. Amer. Ceram. Soc.*, **10** [8], 569–78 (1927).

Description of Apparatus The 2- by 1/2- by 55-inch counterbalanced lever bar is suspended from the under side of a table top by two 3- by 1/4- by 5-inch L's, the knife edges being so placed that the lever operates on an 8 to 1 ratio. The knife edges and the center of the supporting bolt are placed exactly in the center line of the beam. The 1 1/2- by 2- by 8-inch bar that supports the test piece is cut with V-shaped notches 1 1/2, 2 1/2, and 3 1/2 inches from the center line of the hole which is just large enough to allow the 1/2-inch iron rod to move up and down freely. The lower end of the iron rod screws

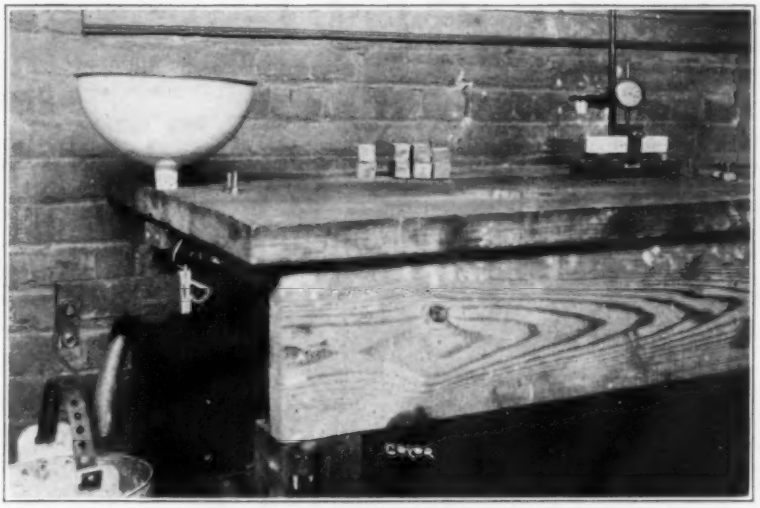

FIG. A15a.

into a stirrup which fits over the first knife edge while the upper end screws into a stirrup which fits loosely around the test piece. The bucket for receiving the shot is supported from the lever bar by a hook attached to a stirrup which fits over the second knife edge. The shot are contained in a box located on top of the table. Three Ames dials are used to detect the amount the specimen bends under a given load. The load is a function of the shot added to the bucket supported from the lever bar, the weight of the shot being obtained on a small double beam platform scale calibrated to 1/4 ounces.

Determination of Transverse Strength The beam being previously counterbalanced, the 1- by 1- by 6-inch test piece if pushed through the stirrup and allowed to rest on the two lower supports which are 3/8-inch diameter iron rods resting in the appropriate V-notches. The 3/8-inch diameter iron rod going through

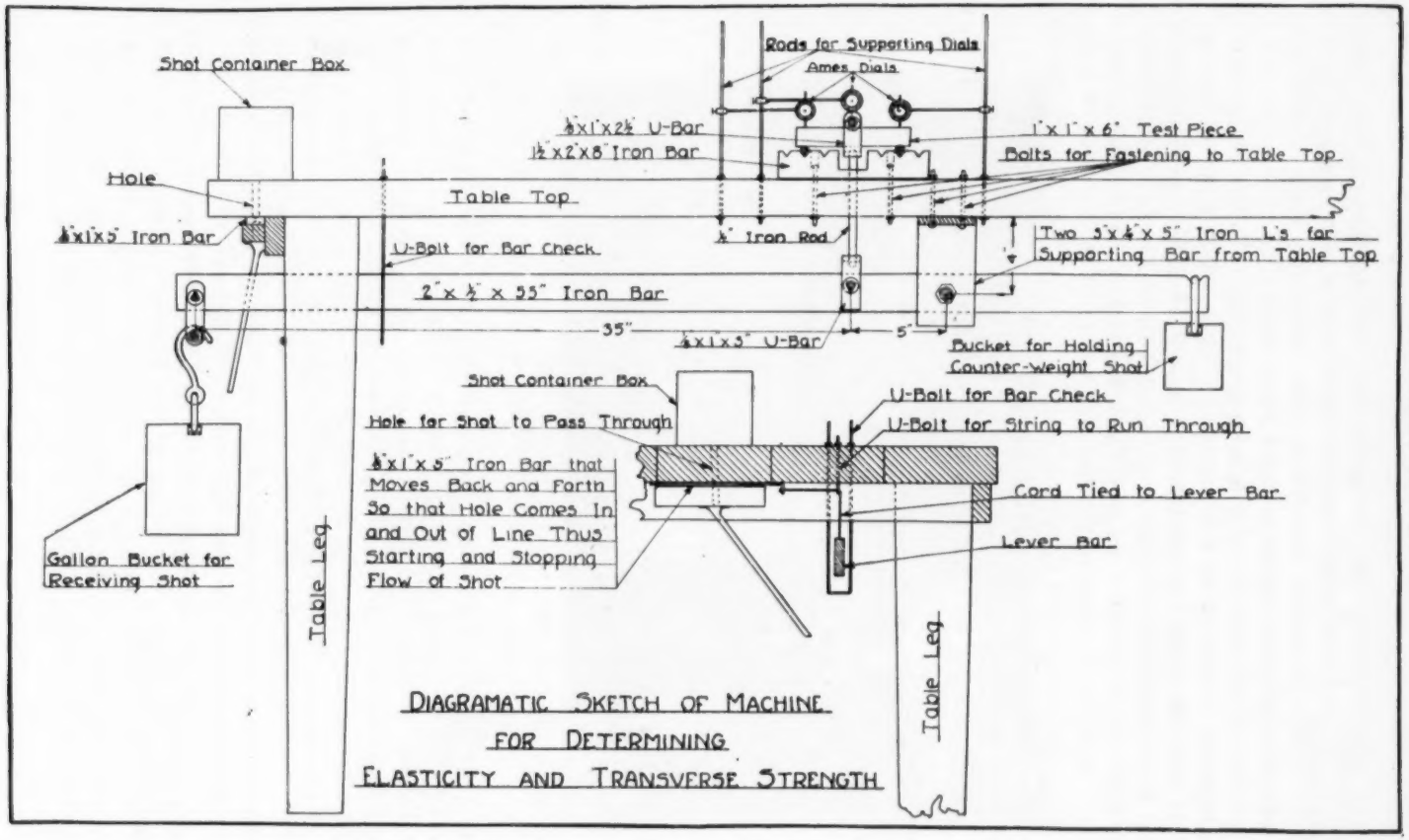
Shot Container Box
Rods for Supporting Dials
Ames Dials
⅜x1"x2½" U-Bar
½"x2"x8" Iron Bar
1"x1"x6" Test Piece
Bolts for Fastening to Table Top
Hole
Table Top
⅜x1"x5" Iron Bar
U-Bolt for Bar Check
½" Iron Rod
Two 3"x4"x5" Iron L's for Supporting Bar from Table Top
2"x½"x55" Iron Bar
35"
⅜x1"x3" U-Bar
5"
Bucket for Holding Counter-Weight Shot
Shot Container Box
U-Bolt for Bar Check
Hole for Shot to Pass Through
U-Bolt for String to Run Through
⅜"x1"x5" Iron Bar that Moves Back and Forth So that Hole Comes In and Out of Line Thus Starting and Stopping Flow of Shot
Cord Tied to Lever Bar
Lever Bar
Gallon Bucket for Receiving Shot
Table Leg
Table Leg
DIAGRAMATIC SKETCH OF MACHINE FOR DETERMINING ELASTICITY AND TRANSVERSE STRENGTH

FIG. A15*b*.—Diagrammatic sketch of machine for determining elasticity.

the stirrup rests on the top of the test piece. The 1/8- by 1- by 5-inch iron bar is pushed back until the 1/8-inch hole comes into line with the hole leading from the shot container box, thus allowing shot to flow into the bucket suspended from the lever bar. As indicated by the diagram, one pound of shot in the bucket places a load of seven pounds on the test piece. When sufficient load is applied to break the test piece, the lever bar falls until it is stopped by the V-bolt bar check. The falling bar pulls the 1/2- by 1- by 5-inch iron bar by means of the cord tied to the lever bar until the 1/4-inch hole is out of line with the hole leading from the shot container box, thus automatically stopping the flow of shot when the test piece breaks. The bucket is lifted from the lever bar and placed on the platform scales to get the weight of shot added, the weight of shot being multiplied by seven to get the load necessary to break the test piece. The depth and breadth of the test piece at the fracture is measured to the nearest 1/64 of an inch.

Calculation of Modulus of Rupture

Transverse strength as expressed in terms of modulus of rupture is calculated as follows:

$$M = {}^3/_2 \frac{(P \cdot l)}{(bd^2)}$$

in which

M = modulus of rupture as pounds per square inch
P = load in pounds required to break test piece (lever ratio times actual weight applied)
l = span in inches over which test piece is broken
b = breadth of test piece in inches
d = depth of test piece in inches.

Accuracy

The apparatus is accurate to about 1/4 of 1% of the load applied. Ten determinations should be made. Values 20% above or below the mean of the values obtained should be discarded. Transverse strength of the material in question is taken as the average of the remaining values but should represent at least 60% of the original number of test pieces.

Determination of Elasticity

Elasticity is determined by means of the apparatus shown in Figs. A15*a* and A15*b*, test specimens 1- by 1- by 6-inches being employed on a 5-inch span. As in determining transverse strength, the load is applied at a rate of about 60 pounds per minute by allowing shot to flow into the bucket attached to the lever bar. The plane of the lower supports or knife edges remains practically constant throughout the determination, but as load is applied to the stirrup or upper knife edge, the test specimen is deflected downward in the middle. The amount the test specimen is deflected is indicated by noting the deflection on Ames dials calibrated in ten-thousandths of an inch, the dials being read before and after

the application of the load. It is essential that the surfaces of the test specimen in contact with the knife edges be practically level and parallel in order to minimize all errors arising from the turning of the specimen as load is applied. In the case of slightly warped test specimens it is desirable that the places of contact be ground until the specimen rests solidly between the knife edges.

The beam being previously counterbalanced, the test specimen is pushed through the stirrup and allowed to rest upon the two knife edges. In order to reduce to a minimum any error caused by the taking up of slack in the apparatus, a load of 21 pounds is applied to the specimen before the initial reading of the dials is taken. This is done by placing a 3-pound weight in the bucket attached to the lever bar. Two of the Ames dials are lowered until the pinions rest respectively on the top of the test specimen at a place directly over the lower knife edges. The other Ames dial is lowered until the pinion rests on top of the upper knife edge. The pinions are gently tapped in order to insure a good seating and the dials read. Load is applied to the test specimen by allowing a definite amount of shot to flow into the bucket attached to the lever bar. Sufficient load should be applied to insure a sufficiently large deflection but should not be enough to break the test specimen. The proper load to apply will, of course, vary according to the type of material being tested but should be about three fourths of that required to break the test specimen. After the definite load has been applied, the dials are again read and the depth and breadth of the test specimen at the stirrup knife edge determined to $^1/_{64}$ of an inch. The difference between the two readings of the center dial shows the amount the test specimen was deflected under the given load. In order to overcome any error caused by the turning of the test specimen on the end knife edges, or actual depression of the test specimen by the knife edges when very soft or unfired pieces are used, the average of the deflections shown by the two end dials is subtracted from the deflection shown by the center dial in order to get the true deflection of the test specimen under the given load.

Calculation of Modulus of Elasticity

The elasticity of the material as expressed in terms of Young's modulus of elasticity is calculated as follows:

$$E=\frac{m\times l^3}{4\times S\times b\times d^3}$$

in which

E = Young's modulus of elasticity as pounds per square inch

m = load in pounds applied to test piece (that is, the load applied after the initial reading of the dials)

l = distance in inches between end knife edges, the 5-inch span being recommended
S = deflection of test piece in inches
b = breadth of test piece in inches
d = depth of test piece in inches

Accuracy Ten determinations should be made. Values 20% above or below the mean of the values obtained should be discarded. Elasticity of the material in question is taken as the average of the remaining values but should represent at least 60% of the original number of test pieces.

NOTE: Where less accurate but comparative results are desired along with speed and simplicity of operation, the following procedure is described wherein only one Ames dial is employed. In this method, transverse strength and elasticity are determined at a single operation.

The beam being previously counterbalanced, the test specimen is pushed through the stirrup and allowed to rest upon the two knife edges. In order to reduce to a minimum any error caused by the taking up of slack in the apparatus, a load of 21 pounds is applied to the specimen before the initial reading of the dial is taken. This is done by placing a 3-pound weight in the bucket attached to the lever bar. The Ames dial is lowered until the pinion rests on top of the upper or center knife edge. The pinion is gently tapped in order to insure a good seating and the dial read. Load sufficiently large to break the test piece is added by allowing shot to flow into the bucket attached to the lever bar. The dial is continuously watched as load is being applied and the reading noted just prior to the breaking of the test specimen. The difference between the initial and final reading of the dial shows the amount the specimen was deflected by the load added after the initial reading was taken, that is, the total load minus 21 pounds. Young's modulus of elasticity and modulus of rupture are then calculated according to the formulas given above. By having three holes for the supporting bolt drilled in the lever bar at different distances from the first knife edge, it is possible to have three different lever ratios, and by suspending the lever bar from the appropriate hole, and the apparatus can be used with the low and intermediate ratios for testing very soft and unfired specimens and the high ratio for testing specimens of very great strength, such as bars made with an electrical porcelain body. Suggested ratios are 1 to 5, 1 to 7, and 1 to 14.

A16. STANDARD CONE MOLD

For record and convenience, the attached detail drawing shows a standard cone mold, made in two parts, and the wood base for assembling same.

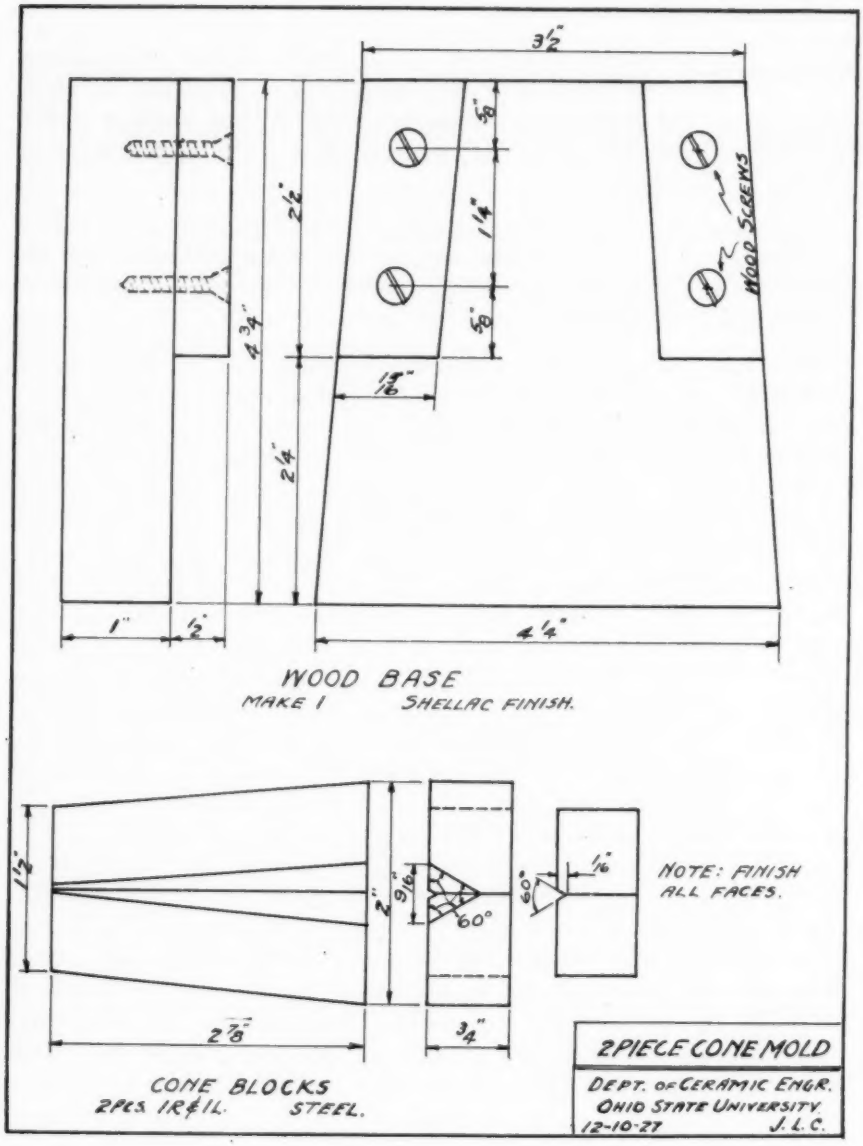

FIG. A16.—Standard cone mold.

The cone produced by this mold is of the same dimensions as the standard pyrometric cones below No. 23, and hence is adapted for making cone tests of feldspar, etc. If the user desires a small cone for test against the high temperature standard pyrometric cones, it is only necessary to cut off the cone produced in this mold to the desired length.

A17. IMPACT STRENGTH APPARATUS

Resistance to mechanical shock may be determined by the number of blows of equal severity, or the number of blows of uniformly increasing severity, required to cause the test specimen to fail, the blow being applied by means of a weight falling under the influence of gravity.

Description of Apparatus The Olsen impact machine (see Fig. A17) designed for this test consists of a weight falling between two guides and striking on a short intermediate bar which rests on the test specimen and by which the impact is transmitted. The weight is raised by means of a trigger attached to a cord actuated by a small motor. A series of adjustable fingers extend from a vertical bar adjacent to the rising weight so that the weight may be released at any elevation desired by releasing the trigger.

Determination of Impact Strength The test specimen of standard dimensions is placed under the intermediate bar and preferably is seated by placing ten sheets of newspaper under it to distribute the load. The blow is then applied until the test piece fails.

The severity of the blow from a given weight is proportional to the velocity, which is proportional to the distance through which the weight

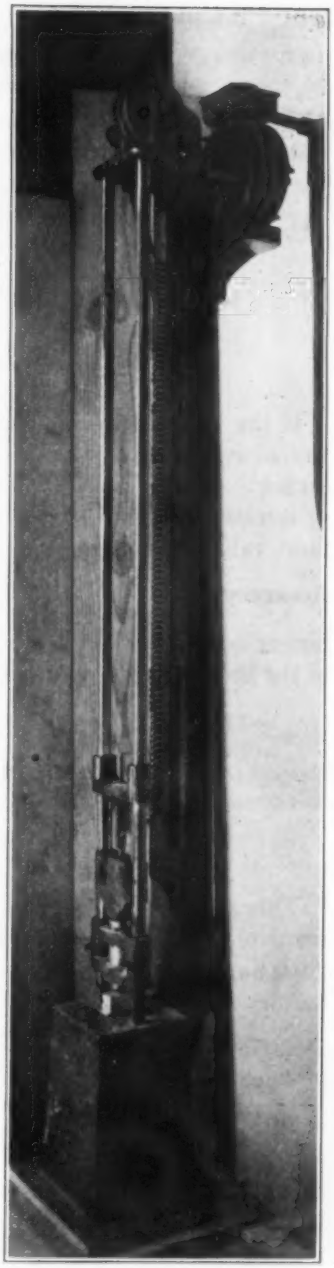

FIG. A17.

falls. Whether the blow is the same throughout the test or is of increasing velocity, the impact strength of the test specimen should be expressed in terms of momentum, *i.e.*, gram centimeters per second at the instant of impact.

Calculation The calculation for a single impact is as follows:

$$M = m \cdot a \cdot \sqrt{\frac{2d}{g}}$$

when

M = momentum at instant of impact
m = weight of falling body in grams
a = accelerations due to gravity = 980
d = distance weight falls in centimeters
g = gravitational constant = 980

If the blow is the same throughout the test, the value obtained by the above calculation must be multiplied by the number of blows struck. If the weight falls through increasing distances as the test progresses, the value d increases with each succeeding blow and the final value will be the sum of the values, M, for all the blows struck.

Accuracy The approved practice is to take the average of ten tests, eliminating any values obtained which are more than 20% higher or lower than the mean of the ten tests. If more than 40% of the tests are thus eliminated, the entire series is rejected.

NOTE The factor of fatigue is not considered in computing the above values, although we recognize that a test specimen which withstands the cumulative abuse of 20 blows of the same velocity has more than two times the impact strength of a specimen that stands ten blows of that velocity.

A18. THERMAL EXPANSION APPARATUS

This apparatus[1] has been found satisfactory for use with test specimens 6- by 1- by 1-inch in size and its accuracy is within the limits of variation of duplicate specimens prepared by usual laboratory or factory methods.

Description of Apparatus The furnace consists of an alundum cylinder 3 inches inside diameter and 18 inches long, wrapped with nichrome wire as an electric heating unit. The ends of the cylinder are closed by means of suitably designed clay refractory plugs. A base of Sil-O-Cel clay mixture is provided and a sheet iron cylinder filled with loose Sil-O-Cel provides the necessary heat insulation. In the bottom plug, a fused silica rod is erected and capped with a refractory seat for supporting the test specimen. In the top plug a loose rod of fused silica is inserted for transmitting

[1] Described in *Jour. Amer. Ceram. Soc.*, **10** [8], 569 (1927).

the expansion of the test specimen to an Ames dial, rigidly installed above the furnace and calibrated in thousandths of an inch. The temperature of the test specimen is determined by means of a thermocouple connected with a potentiometer and carefully standardized.

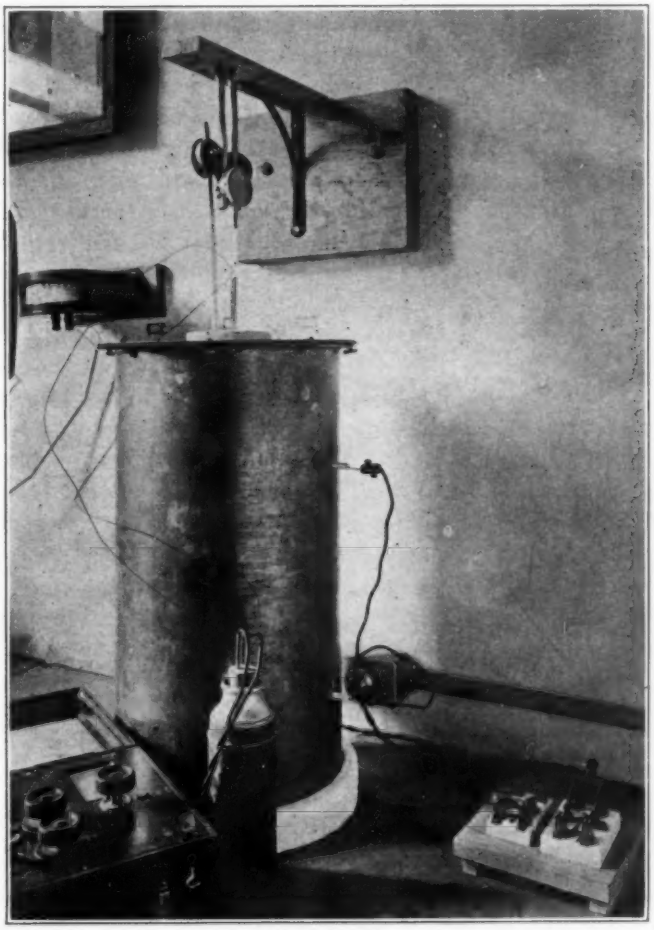

FIG. A18*a*.

This thermocouple extends to the bottom of the test specimen, and is inclosed, except at the junction of the elements, in a refractory two-hole tube. This tube may be raised and lowered to obtain the temperature at bottom, middle, and top of the test specimen or if desired additional thermocouples may be installed so that the necessity of raising and lowering the thermocouple is eliminated.

Determination of Thermal Expansion

This apparatus having been carefully standardized by means of a well-annealed fused silica bar inserted in place of the test specimen, the outfit is ready for use. The test specimen is carefully measured at room temperature and length and temperature recorded. It is then inserted in the furnace and the top rod inserted. The pinion of the Ames dial is rested against the top end of the silica rod. The furnace is then heated to the desired temperature and maintained at that temperature by means of a rheostat for about 20 minutes in order to insure a uniform temperature throughout the test specimen. The expansion of the test specimen is recorded on the Ames dial and, after correction for the expansion of the base and rods, this value is the linear expansion of the test specimen.

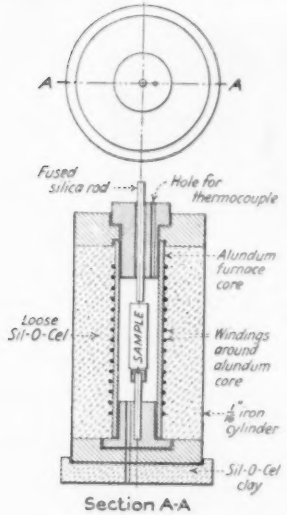

FIG. A18b.

Calculation

Thermal linear expansion is expressed as the coefficient of linear expansion which is calculated as follows:

$$a = \frac{L - l}{l(t^1 - t)}$$

in which

a = coefficient of linear expansion over the interval $(t^1 - t)$°C
L = length of test specimen at final temperature (t^1) in cm.
l = length of test specimen at room temperature (t) in cm.
t^1 = final temperature attained in furnace in degrees C
t = room temperature in degrees C

A19. MECHANICAL ENDURANCE APPARATUS

The apparatus shown in Fig. A19 is designed to show the ability of the material in question to withstand comparatively small but continuous mechanical shock, the severity of the shock being of such magnitude that from one to ten thousand blows of the hammer are required to cause failure of the test specimen. Thus, the test is essentially one of endurance or fatigue and gives an idea as to the combined effects of hardness, elasticity, crushing strength, etc. The apparatus requires very little attention during a determination because the number of blows is automatically counted and the motor stops shortly after the failure of the test specimen. In order to reduce to a minimum the errors due to surface irregularities, ten layers of

ordinary newspaper are placed underneath the test specimen. For testing abrasives, fire brick, heavy clay products, etc., it is recommended that 1-by 1-by 2-inch test specimens be employed.

Description of Apparatus

The apparatus consists essentially of a motor and speed reducer for operating a cam which lifts the hammer and allows it to fall. The number of blows is automatically recorded by the small counter shown in the fore-

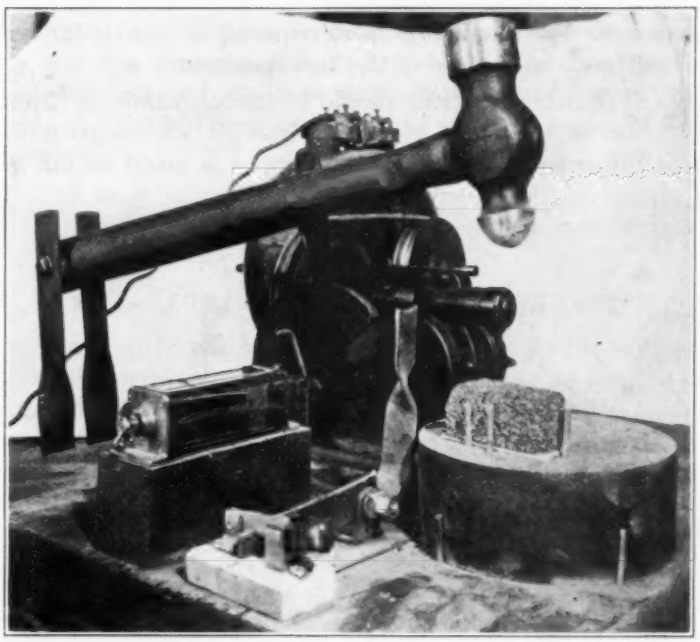

FIG. A19.—Mechanical endurance apparatus.

ground of the photograph. The small arm attached to the cam operates the counter. The hammer weighs about 800 grams and is allowed to fall a distance of three inches before striking the test specimen. The hammer strikes about 20 blows per minute and gradually wears a hole in the test specimen. In order to avoid forming an ever-increasingly large hole, the pien end of the hammer is ground to a uniform diameter of $^5/_8$ inch. When the test specimen breaks, the hammer falls far enough for the handle to strike the lever and throw the switch, automatically stopping the motor. The test specimen is held loosely in place by small rods inserted in the heavy iron block on which the test specimen rests.

Determination of Mechanical Endurance The counter having been previously turned back to zero, the test specimen is inserted in its place and the test begun by closing the switch which starts the motor. When the test specimen breaks, the number of blows required to cause its failure is read on the counter. Of course, the number of blows required to cause failure will depend very largely on the class of material being tested. If the material is especially resistant, an additional weight of 500 grams is added to the hammer in the form of a steel cap turned so as to fit the head of the hammer. The number of blows required to cause failure is taken as the mechanical endurance of the test specimen.

Accuracy Ten determinations should be made. Values 30% above or below the mean of those obtained are questionable and should be discarded. Mechanical endurance is taken as the average of the remaining values and should represent at least 60% of the original number of test specimens.

A20. CRUSHING STRENGTH APPARATUS

Figure A20 shows an electrically operated Olsen hydraulic press of 200,000 pounds capacity, it being equipped with several interchangeable lever weights so that varying degrees of sensitivity are attainable. It is essential that the test specimens be of a uniform size and shape, that the pressure be uniformly distributed, and that the load be applied directly perpendicular to the horizontal axis of the test specimen. In order to insure a uniform distribution of the pressure, three layers of ordinary cardboard are inserted between the test specimen and both the top and bottom pressure plates of the apparatus. During a determination the test specimen imbeds itself in the cardboard and any irregularities in the surfaces adjacent to the pressure plates are compensated for. Cardboard has been found to give amply satisfactory results and is very much more convenient and less expensive than capping the test specimen with cement, plaster, lead plates, grinding the ends perfectly smooth, etc. The size and shape of test specimen will govern somewhat the magnitude of the results obtained and will depend largely upon the type of material being tested. For grinding wheels and allied materials, a 3-inch diameter wheel two inches in thickness is recommended. For testing heavy clays, fire clays, and allied materials, a cubical specimen three inches on a side is recommended. For testing whiteware bodies and allied materials, a cubical specimen two inches on a side is recommended. The apparatus is suited for making determinations on regular commercial size fire brick, drain tile, grinding wheels, wall tile, etc.

Description of Apparatus The large press frame shown at the left of the photograph is especially suited for testing large specimens. The pressure plates, between which the test specimen is located, are made of very hard steel and are not liable to be injured in testing ceramic materials. The upper pressure plate can be raised and lowered by means of the hand screw, thus accommodating various sized test specimens. The plunger that forces the liquid into the base of the press, thus giving rise to the hydraulic pressure, is forced downward by means of the motor driven screw shown at the center of the photograph. The lever bar is counterbalanced by the appropriate weights and the pressure actually applied to the test specimen is determined by running the lever weight out on the lever bar (keeping the lever bar balanced until the specimen fails) by means of the small hand screw.

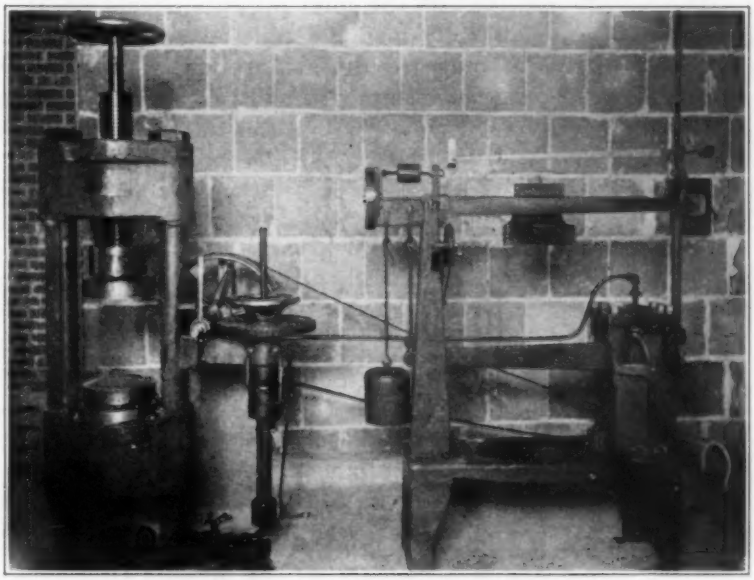

FIG. A20.—Crushing strength apparatus.

Determination of Crushing Strength The test specimen is placed upon the lower pressure plate, the lever bar weight having been previously placed at the zero reading of the scale. The top pressure plate is screwed tightly down upon the test specimen by means of the hand screw. Pressure is applied to the test specimen by operating the small hand lever attached to the press frame which throws the driving pulley into gear with the plunger which is then screwed downward. As pressure is applied, the lever bar is maintained

in the horizontal or balanced position by moving the lever weight along the bar by means of the small hand screw. The driving pulley is disengaged from the plunger screw by means of the small hand lever as soon as the specimen fails. The pressure required to cause the test specimen to fail is read to the nearest hundred pounds from the scale attached to the lever bar.

Calculation of Crushing Strength The crushing strength of the test specimen as expressed in terms of pounds per square inch is calculated as follows:

$$C = \frac{P}{a}$$

in which

C = crushing strength in pounds per square inch
P = pressure in pounds required to cause failure of test specimen
a = cross-sectional area in square inches of smallest section of test specimen

Accuracy For the best results the total pressure should be at least 15,000 pounds. The load is applied at a slow and uniform rate so that very satisfactory results are attainable providing uniformly sized test specimens are employed and care is exerted to avoid all forms of eccentric loading. Ten determinations should be made. Values 20% above or below the mean of the values obtained should be discarded. Crushing strength of the material in question is taken as the average of the remaining values but should represent at least 60% of the original number of test pieces.

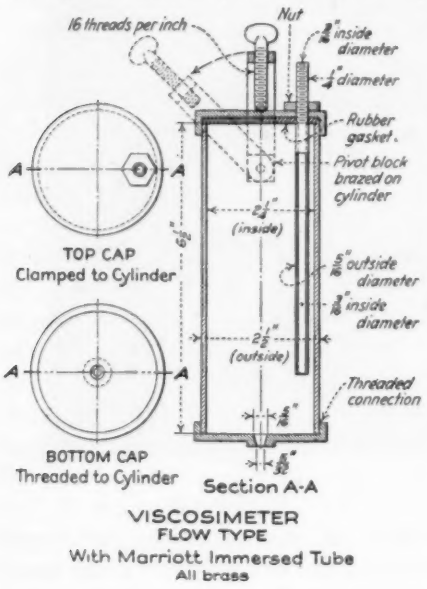

FIG. A21a.

A21. VISCOSITY MEASURING APPARATUS

(The Mariott Tube Flow Viscosimeter)

Description of Apparatus This apparatus introduced by Bleininger and Hornung[1] consists of a brass cylinder closed at the top except for an air-inlet tube which extends through the top cap down almost to the outlet. The air intake is located near the side of the cylinder and the liquid outlet in the center of the bottom

[1] *Trans. Amer. Ceram. Soc.*, **17**, 331 (1915.)

cap to prevent the outflow being influenced by the action of the incoming air which bubbles to the top of the liquid being measured. This air-intake tube provides a relatively constant pressure on the liquid at the point of outlet as long as the surface of the liquid is above the outlet of the air-intake tube. The apparatus is shown in detail in Figs. A21*a* and A21*b*, as modified for use in the ceramic laboratories at Ohio State University.

Operation of Apparatus The liquid after thorough agitation is placed in the cylinder through the top openings by removing the cap, the outlet being closed by the tip of the finger. With the cap in place, the outlet is uncovered and the time required for a given amount of liquid to flow out is recorded. The apparatus is then thoroughly cleaned and the same test run on water, which is the unit of value.

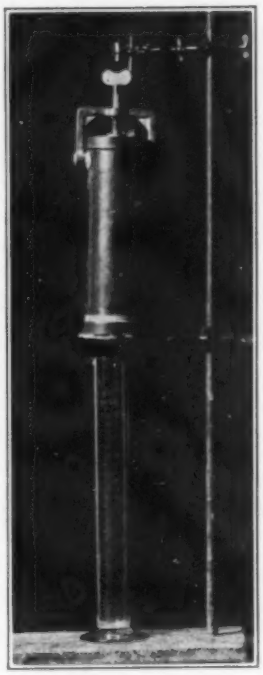

FIG. A21*b*.

Calculation The amount of time necessary for a given amount of water to flow out is taken as unity and the time necessary for the same amount of any other liquid to flow from the same apparatus divided by the unit time for water gives a value which is accepted as the relative viscosity of the liquid being tested.

Accuracy This apparatus has been found fairly satisfactory for measuring viscosities of slips and glazes which are of moderate specific gravity, but if the suspended material settles quickly or the liquid is extremely viscous, the values are not reliable. At least, three check tests should be run on any liquid being tested.

A22. TEST FURNACE FOR DETERMINING P.C.E. VALUES

(Mellon Institute Design)

The low pressure regulator used in this apparatus is manufactured by the Chaplin-Fulton Manufacturing Company, 29 Penn Avenue, Pittsburgh, Pa., and has a one-inch inlet and outlet. The injector used to inject the gas was supplied by the Denver Fire Clay Company, Denver, Colo. The test furnace is also made by the Denver Fire Clay Company, and bears the designation "Type 392," gas-fired. The 100-gallon pressure equalizing tank is simply a drum of the type commonly

used to ship liquids. The other parts of the apparatus are simple and require no explanation.

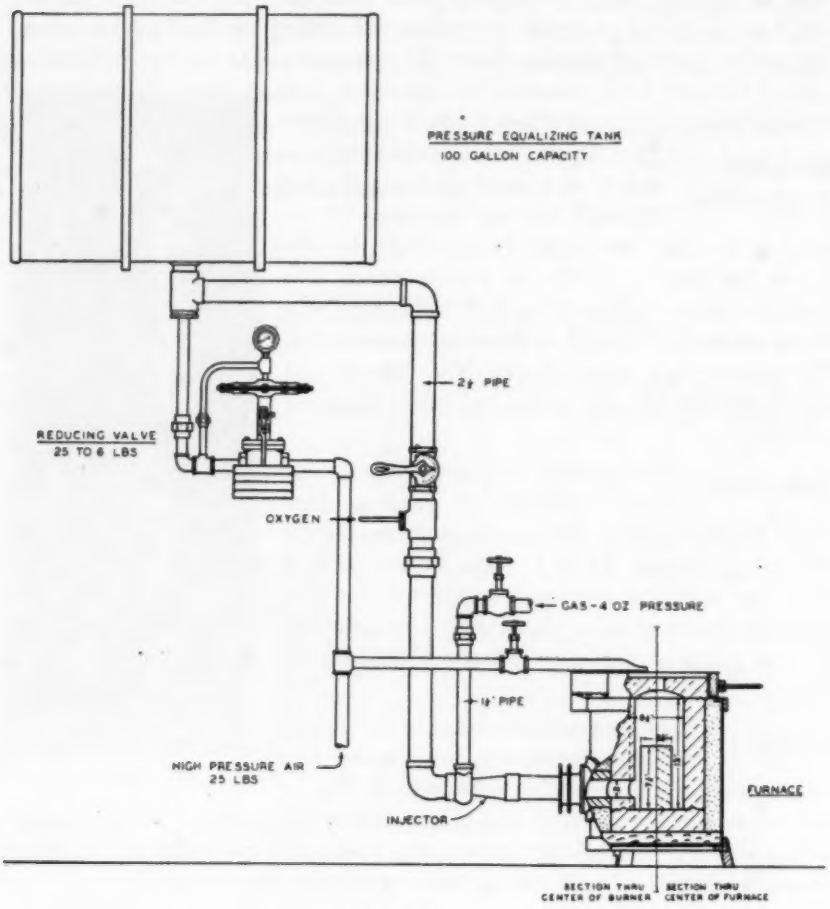

FIG. A22.

A23. A Platinum-Wound Resistance Furnace With Chromel A Booster Coil[1]

The design is as shown in Figs. A23*a* and A23*b* herewith, except that the Chromel Booster Coil was wound on the outside instead of inside of the flue lining.

The platinum resistor is 54 ft. of No. 16-gage round wire, 80% platinum, 20% rhodium, having electrical constants as follows: (1) tem-

[1] Edward Orton, Jr. and J. F. Krehbiel, *Jour. Amer. Ceram. Soc.*, **10** [5], 373 (1927).

perature coefficient per degree, 0.0012 ohms, and (2) resistance per foot at 0°C, 0.052 ohms.

This was wound on the tube control on wooden mandrels in a lathe and fed on under some tension, the ends of the coil being secured by clamps. The coil was then heated to anneal it, so that the coil would remain in place. It was then given several coats of alundum cement, No. 518, mixed with paste and heated to burn out the paste and set the cement. The 54 feet coiled on the tube $3^{3}/_{4}$ inches external diameter gives a center to center spacing of about $^{3}/_{8}$ inch.

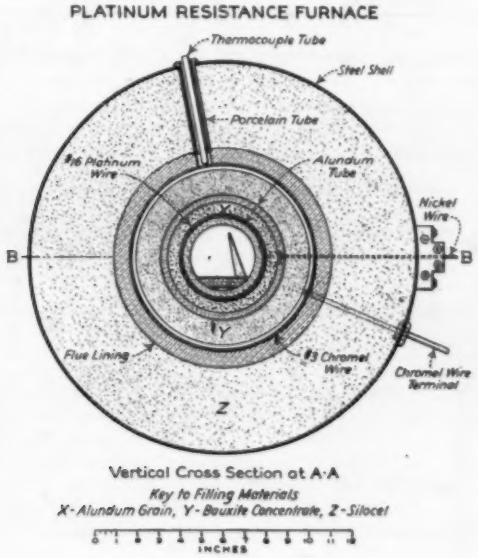

FIG. A23a.

Platinum end coils are each 10 feet of No. 22 gage wire, 80% platinum 20% rhodium. Booster coil is 70 ft. of No. 3 round Chromel A Wire.

Construction Details The drawings show details of the construction. The primary coil terminals were brought outside the high-temperature area, and fastened into pure nickel blocks of large cross-section, from which pure nickel wire of heavy cross-section connected with the copper feed circuits. The Chromel wire terminals were made by doubling the wire and welding it, and carrying the doubled cross-section outside to the feed wire. To enable the temperature of the booster coil to be carefully watched to prevent its burning out, a thermocouple tube was built in from the exterior to the level of the Chromel wires, and a base metal thermocouple installed in it.

Inside the 8-inch tube at either end, is a ring made of alundum grain and alundum cement, fired at cone 20. This ring is $^3/_4$ inch thick, with a groove $^1/_4$ inch deep, to receive and support the ends of the 5-inch alundum tube.

By the arrangement of end plates and disks, it is easy to take out the two alundum tubes or either of them, and the packing material, for examination or replacement, without touching the Chromel coil

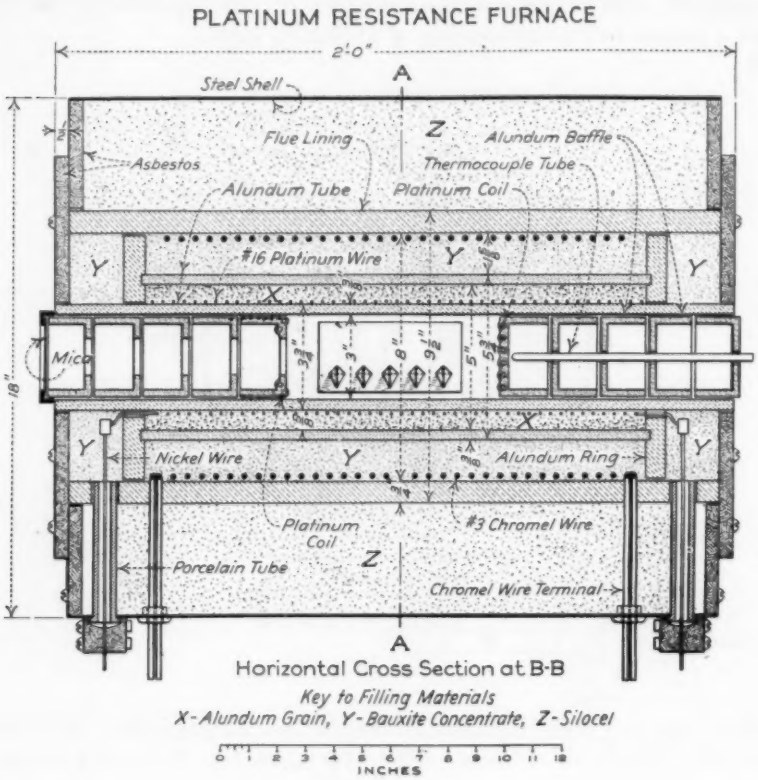

FIG. 23*b*.

or the external parts of the furnace. Once installed, this outer coil should last almost indefinitely, as No. 3 Chromel A wire will stand a lot of work if kept below 1200°C.

Within the internal tube, is a series of five partitions at each end. These partitions are made with flanges, sliding in the tube freely, in effect making shallow flat-bottomed cups. The outside dimensions of these cups are $1^5/_8$ inches long by $2^{15}/_{16}$ inches in diameter, with a $^3/_{16}$-inch wall. They are made of alundum grain and cement, fired to cone 20. The front set has a central opening for observation, and the

back set has a $^5/_{16}$-inch hole for a pyrometer tube. Both sets have two $^1/_8$-inch holes, $1^1/_4$ inches apart, for the terminals of the heating coils to pass through. These heating coils necessarily have to be able to go a little higher than the temperature of the side walls of the tube, because of the slight draft of air passing longitudinally through the furnace at times, carrying out heat. Also, the observation hole in the front allows radiation. Hence, they have to be wired with platinum-rhodium resistors, calculated to give even heavier heating effect than the sides. The end coils each consist of 10 feet of No. 22 gage wire, of the 80% platinum 20% rhodium alloy, wound in a spiral on a $^1/_8$-inch

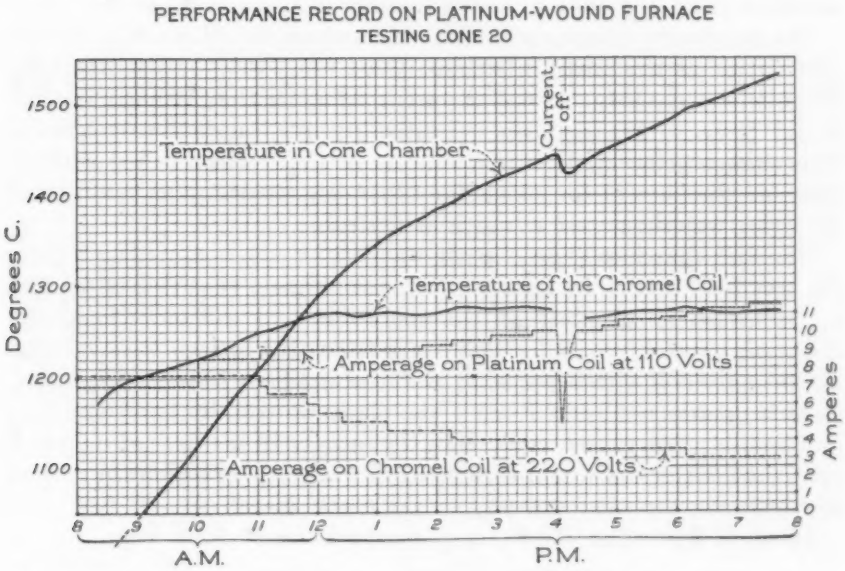

FIG. A23*c*.—For cost data on construction and operation see original article cited above.

rod, and imbedded in grooves cut in the front and back partitions. Each coil has a resistance of six ohms, together with a maximum of 12 ohms rheostat resistance, and is used in our case on a 60-volt current, but could be used on 110-volt equally well.

First Operation of the Furnace For the first few runs, the furnace was tried on 60-volt current on the primary coil, with the regular current of less than 5 kilowatts on the Chromel booster coil. The latter functioned well, though a little slower than was anticipated. As the furnace neared its maximum, there was little current left on the booster, and the furnace still had not reached its desired temperature. It became apparent that it would be necessary

either to increase the space between the two coils, or insulate more effectively in the space already provided. The latter expedient was tried.

A pure aluminum oxide, known as bauxite concentrate, grade A, was procured from the Aluminum Company of America, which is very fine-grained (300-mesh) and only one-half as dense as the fused alundum grain. It acts as a very good insulator, and its heat-resisting power without change of volume is also excellent. The alundum grain between the outer alundum tube and the Chromel coil was replaced with this lighter finer material. It proved to insulate the Chromel coil against the out-flowing heat of the primary coil, enough better than the alundum grain had done to save any other changes being made.

The maximum temperature which the furnace would reach on the 60-volt circuit as the result of several trials was 1460°C. Also, the time required was too long. It was apparent therefore that 110-volt current would have to be used, as indicated by the original calculations. This change being made, a temperature of 1533° was reached without using all the current for which the controls provided, and the time of the firing was shortened as much as desirable.

The fact that but little current was left on the booster coil during the last 100° rise of the furnace does not indicate that it is of no use. Its value lies in speeding up the operation, and still more in saving the platinum coil from many hours of service per heating. By encircling the primary coil with a hot zone, the heat gradient from that coil outward is greatly reduced. Even if the platinum coil, by hard crowding and long-heating period, could heat the furnace to the desired temperature, the booster coil would still be worth while in shortening the period, and reducing the wear and tear on the costly metal.

Speed of Operation The rate of temperature increase was:

1200–1300°C	75 min.	or 80° per hr.
1300–1400°	140 "	" 43° " "
1400–1500°	200 "	" 30° " "

The actual elapsed time on the last 100° was 240 minutes, but the shutting off of the power occasioned a clear loss of 40 minutes in the program of the operation. It would have been quite possible to drive the furnace up at a higher rate than was done, but for the purposes in view, this was quite fast enough. For other industrial purposes, the speed of operation might be a more critical factor in determining the value of this equipment. It is probable that at least 40° per hour between 1400 and 1500° can be safely reached and perhaps 50°; 60–75° per hour from 1300–1400°; certainly 100° per hour can easily be had from 1100° to 1300°.

CERAMIC ABSTRACTS

Compiled by the

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Abrasives

Centerless grinding practice expedites British production. I and II. W. OGILVIE. *Abrasive Ind.*, **7,** 48–51 (1926).—The operation of centerless grinding machines is described, discussed, and illustrated by diagrams, and the advantages of centerless grinding are discussed. (*J.I.M.*)

Polishing abrasives described. FRED B. JACOBS. *Abrasive Ind.*, **7,** 80–82 (1926).—A short account of the properties, sources, and uses of the commoner abrasives: emery, corundum, carbide of silicon, manufactured alumina, tripoli, amorphous silica, lime, rouge, crocus, and pumice. (*J.I.M.*)

Modern applications of disk grinding. FRANK W. CURTIS. *Amer. Machinist*, **64,** 385–89 (1926).—A variety of examples is given of work being successfully ground on hand, semiautomatic, and automatic grinding machines. (*J.I.M.*)

Standard types of grinding wheels. ANON. *Amer. Machinist*, **65,** 465 (1926).—Limiting dimensions recommended for spindles, wheel types, designations, and standard letter dimensions used for ordering wheels as recommended by the Simplified Practice Committee of the Bureau of Standards are tabulated and illustrated. (*J.I.M.*)

Using and abusing diamonds. JOHN R. GODFREY. *Amer. Machinist*, **66,** 244 (1927).—The increasing use of diamonds for turning and cutting materials, including metals from aluminium to cast iron, is announced. Diamonds should be ground with the right sort of cutting edge by means of copper or close-grained cast iron, charged with diamond dust. Other points concerning the correct use of diamonds as cutting tools are described. (*J.I.M.*)

Centerless-feed polishing machine. ANON. *Amer. Machinist*, **66,** 559 (1927).—A centerless-feed polishing machine made by the Production Machine Co., Greenfield, Mass., is illustrated and described. The belt can be adjusted to run in either a vertical or a horizontal position, and a taper spindle is provided for miscellaneous internal work, such as finger holes in scissors, etc. (*J.I.M.*)

Polishing on a production basis. ANON. *Brass World*, **22,** 24 (1926).—An illustrated description of an automatic polishing machine for polishing cast-iron and brass hot-air registers. (*J.I.M.*)

New A.C. polishing lathe. ANON. *Brass World*, **22**, 121 (1926).—An illustrated description is given of a new selected speed, gear-driven, noiseless polishing and buffing lathe made by the Crown Rheostat and Supply Co. of Chicago. The polishing speeds are not variable, but may be selected to give the correct value. (*J.I.M.*)

New polishing machine. ANON. *Brass World*, **22**, 164 (1926).—A new automatic machine made by the Divine Bros. Co. of Utica, N. Y., for polishing flat stock and flat surfaces, is described. The material to be polished is placed on a feed belt which carries the work under a series of polishing wheels where the whole process is completed mechanically. Anything from thin sheet to metal several inches thick can be polished, and the width can be as much as 20 in. Contact between the work and the polishing wheels is maintained by micrometer adjustment, and the wheels are both weight- and spring-balanced. Each wheel is driven by an independent direct drive motor. (*J.I.M.*)

New polishing machines. ANON. *Brass World*, **22**, 331 (1926).—Two new polishing machines made by F. B. Stevens, Inc., of Detroit are described. One is a strip polishing machine which automatically polishes both sides of the metal strips up to 6 in. in width. The second is a machine for tube polishing. (*J.I.M.*)

"Buffing" of metals. WALTER S. BARROWS. *Can. Foundryman*, **17** [4], 24 (1926).—Conditions necessary to obtain satisfactory buffed surfaces are discussed. The importance of a suitable deposit is emphasized. Cyanide copper and brass solutions should not become too low in cyanide as a deposit from such a solution is difficult to "color" and will not spread well. A speed of 2500 r.p.m. is sufficient for all ordinary classes of work. The importance of suitable working conditions and efficient removal of dust is indicated. (*J.I.M.*)

Importance of glue in metal polishing. WALTER S. BARROWS. *Can. Foundryman*, **18** [5], 17–19 (1927).—The importance of suitable glue for the preparation of polishing wheels is emphasized. Ordinary "furniture" glues and bone glues are unsuitable, and only "first run" hide glue should be used. Flexibility is a most important property of a glue used for this purpose, as some slight movement of the grains of abrasives always takes place, and if a brittle glue is used, the grains are broken off. The glue should not be heated above 140°F in melting, and aluminium glue kettles are the best. Small quantities should be melted, as the practice of melting up large amounts and then allowing part to cool for subsequent remelting is harmful. Slow drying is essential. B. gives extensive quotations from a book by Bradford H. Divine, "The Use and Treatment of Glue for Polishing." (*J.I.M.*)

Grinding wheels. J. DAUTRÉBANDE. *Chal. et Ind.*, **7**, 636–38 (1927).—A general account is given of the construction of grinding wheels, these being divided from the point of view of chemical composition into corundum (natural and artificial) and Carborundum wheels. The grading of wheels according to the size of grain is described. The importance of careful mounting, inspection, and guarding is emphasized, and a table is given showing correct speeds for wheels of various grades and diameters. (*J.I.M.*)

Electric driving grinder. ANON. *Iron Steel Canada*, **10**, 76 (1927).—An electrically driven grinder made by the Standard Electrical Tool Co. of Cincinnati is described. This is made in 2 sizes of which the 5 H.P. capacity size carries emery wheels 18 x 3 in., while the 3 H.P. size carries wheels of either 12 x 2 in. or 14 x 2 in. (*J.I.M.*)

Metal polishing methods. ANON. *Machinery* (London), **27**, 584–86 (1926).—Selection and shape of wheels, method and speed of operating, and the best pressure to use in grinding are discussed. The main subject is the polishing of steel, but a few notes are included on polishing nonferrous metals. (*J.I.M.*)

Metal polishing by modern methods. ANON. *Machinery* (London), **28**, 46–50 (1926); (N. Y.), **32**, 563–67 (1926).—The use of specially formed polishing wheels when

finishing a variety of metal parts is described and illustrated. The work described includes the finishing of copper-plated and nickel-plated cycle parts, brass fire extinguishers, door-knob ferrules, faucets, and aluminium magneto parts. (*J.I.M.*)

The use of glue with abrasives for polishing. ANON. *Machinery* (London), **28,** 82–83 (1926).—The method of making the strength test for glue is described, and the way in which glue should be prepared for use with abrasive wheels is discussed. (*J.I.M.*)

Loading of grinding wheels. ANON. *Machinery* (London), **28,** 660 (1926). **Discussion.** EUSTACE J. BEDFORD. *Ibid.*, **29,** 12 (1926).—The general belief that a soft wheel is less liable to load than a hard wheel is questioned, but is upheld by B. Increasing the work speed, decreasing the wheel speed, decreasing the diameter of the work, and decreasing the diameter of the wheel all lead to a softer cutting action. (*J.I.M.*)

Compounds for cutting, grinding, and rust prevention. J. A. MAGUIRE. *Machinery* (N. Y.), **32,** 478 (1926).—It is claimed by the makers that "Oakite" holds oil in perfect suspension in water, making an ideal cutting and cooling compound for use with machine tools and grinding machines. It reduces the tendency for rust to occur, and in grinding machines it prevents the oil from gumming the wheels. It has also been used as a dip after pickling copper plates in order to prevent tarnishing. (*J.I.M.*)

Polishing table ware. ANON. *Machinery* (N. Y.), **32,** 903–904 (1926).—An account of the methods and grades used in polishing knives and silverware. (*J.I.M.*)

Investigating grinding wheel accidents. ANON. *Machinery* (N. Y.), **33,** 203 (1926). —A list of questions that should be answered in investigating grinding wheel accidents is given. (*J.I.M.*)

The prerequisites of successful grinding. BRADFORD H. DIVINE. *Mech. Eng.*, **49,** 975–79 (1927).—D. describes the conditions needed in the polishing departments for producing the highest quality work with minimum cost of material and wages. The most important consideration in successful polishing is the glue used in bonding the abrasive to the wheel, and its treatment. Next in importance are the abrasive materials, of which emery and artificial grains made from bauxite are discussed in detail. Other important factors are (1) design of the article to be polished, (2) absence of vibration in the wheel, (3) proper housing of the polishing department, (4) different kinds of polishing machines, (5) automatic polishing, and (6) polishing tools used for different purposes. (*J.I.M.*)

Preventing grinding wheel accidents. ANON. *Ry. Mech. Eng.*, **100,** 289–90 (1926). —Recommendations from the safety code approved by the American Engineering Standards Committee. (*J.I.M.*)

Better abrasives. ANON. *Sci. Amer.*, **136,** 125 (1927).—A process has been developed for eliminating undesirable needle-shaped grains when grading abrasives. (*J.I.M.*)

PATENTS

Method or process of cementing pulp stones. HERBERT O. KEAY. U. S. 1,655,371, Jan. 3, 1928. A pulp grinding stone consisting of several parts having their adjacent surfaces coated with a solution of a resin dissolved in an organic solvent and united by a cement containing sand, a resin, and an organic solvent.

Internal grinder. SOL EINSTEIN. U. S. 1,662,821, March 20, 1928. A grinding machine combining a work-holder; means for rotating the work-holder; a grinding-wheel; means for giving it movements of predetermined length toward and from the work-holder; means permitting the grinding wheel to be moved to an abnormal position; and automatically actuated means rendered operative at the beginning of the abnormal movement to arrest the rotation of the work-holder.

Grinding machine. PAUL STONER. U. S. 1,663,148, March 20, 1928. In an abrading machine, a carriage gearing to reciprocate the same, a control lever for the gearing, a yieldable plug extending upward from the lever, dogs on the carriage adapted to engage the plug and swing the lever from side to side, said lever being also swingable toward and from the carriage, and the dog having a beveled face adapted to ride over the plug in one position of the lever without moving the lever, substantially as set forth.

Mechanism for truing and dressing grinding wheels. FERDINAND J. HOHNHORST AND FERDINAND J. KROEGER. U. S. 1,663,703, March 27, 1928. In mechanism for truing and dressing grinding wheels, the combination of a head comprising a pair of outer fork-arms and an intermediate fork-arm complemental to the respective outer fork arms and forming a pair of yokes having an integral intermediate fork-arm which is common to both yokes, an axle for each yoke, each of the outer fork-arms comprising a supporting portion at its outer end, a releasable cap for each supporting portion, the intermediate fork-arm comprising an intermediate duplex supporting portion at its outer end, a releasable intermediate duplex cap for intermediate duplex supporting portion, the axles located in nonparallel endwise relation, the outer ends of the axles located in the 1st-named supporting portions and clamped in place by the 1st-named releasable caps, and the inner ends of both axles located in the intermediate duplex supporting portion and clamped in place by the duplex cap, each axle provided with shoulders at its respective ends coacting respectively with the outer supporting portions and intermediate duplex supporting portion for endwise positioning of the axles, and the proximate ends of the axles provided with parallel abutting end faces having opposite inclinations from the same sides of the respective axles and of the same degree to the longitudinal axes of the respective axles and coacting with each other for resisting rotations of both axles, and abrading wheels rotatable about the respective axles.

Grinding machine. JAMES N. HEALD, ALBERT TURNER, AND GEORGE C. KIMMEL. U. S. 1,663,760, March 27, 1928. In a grinding machine, wheel feeding mechanism comprising a ratchet-wheel and pawl, the latter being movable on its operative stroke always to the same point, an irregular but peripherally smooth cam without jogs or breaks in its surface for limiting the return or inoperative stroke of the pawl, and indicating means associated with the cam for procuring its adjustment for the desired number of ratchet-wheel teeth to be passed over by the pawl on its inoperative stroke, the cam being turnable in either direction of rotation to the desired adjustment, by reason of its smooth surface, without the necessity of otherwise moving the parts for which it acts as a stop.

Centerless work guide. LESTER F. NENNINGER. U. S. 1,663,991, March 27, 1928. A work guide for a centerless grinder including a support, a work rest carried by the support, spaced rock shafts carried by the support, guide members rising from the shafts on opposite sides of the work rest, and means for rocking the shafts to vary the position of the guides with respect to the work rest.

Grinding machine. JACOB DE KONING. U. S. 1,664,024, March 27, 1928. In a machine of the character described: a hollow column; a tool rotatably mounted on the column and having an operating pulley; a rotatable driving element having a pulley below the 1st-mentioned pulley; a sleeve turnably mounted around the column; a knee having a vertical movement on the sleeve; a table having a movement on the knee toward and away from the column; a work-supporting carrier having a movement on the table transverse to the table's movement and having a rack; a shaft rotatably mounted on the table and carrying a gear meshing with the rack and having a sprocket wheel and a crank at one side of the machine; a shaft rotatably mounted on the table parallelly with the 1st-mentioned shaft and having a sprocket wheel and a crank on the opposite side of the machine; a chain on the sprocket wheels; a belt carried by pulleys and extending in the hollow column.

Size indicator for surface grinders. CARROLL KNOWLES. U. S. 1,664,823, April 3, 1928. An indicator device for surface grinders comprising in combination, a fixed support, an indicator movably mounted on the support, means to remove the indicator from its operative position and return it to its operative position, said means being operated by movement of the wheel toward and from the work supporting table of the grinder.

Grinder. OTTO SANN. U. S. 1,664,949, April 3, 1928. A grinder comprising, in combination a fixed vertically disposed housing having a pair of forwardly projecting arms, a shaft mounted in the upper ends of the arms, a grinding wheel support having its upper end journaled on the shaft so as to permit oscillating movement of the support relative to the shaft, a second shaft journaled adjacent the lower end of the support, a grinding wheel on the 2nd-named shaft, a motor on the housing, means for transmitting power from the motor to the 2nd-named shaft to rotate the shaft and grinding wheel, a power shaft journaled in the housing, a fly-wheel fixed on the power shaft, a second motor, gearing connecting the second motor with the power shaft, a 2nd shaft journaled in the housing, gearing connecting the last-named shaft and the power shaft, and at least one connecting rod having one end eccentrically mounted on the last-named shaft and having its other end connected to the grinding wheel support, whereby the support is oscillated.

Grinding machinery. JOHN E. CASTER. U. S. 1,665,084, April 3, 1928. A machine of the character described, including opposed grinding and regulating wheels and an intermediate work rest, the wheels having contoured work engaging portions disposed in opposition one to the other, advanceable means for shifting the work along the throat between the wheels, and means for intermittently imparting an advancing movement thereto.

Grinding machine for mill burrs, etc. CONRAD A. RYAN. U. S. 1,665,177, April 3, 1928. A machine of the class described comprising a support, a carrier shaft journaled on the support having a rotary carrier member mounted on the inner end thereof, a grinding shaft journaled on the support and extending transversely to said carrier shaft, a grinding wheel on said grinding shaft, means for moving the grinding wheel in both directions across a portion of the carrier member, and means for adjusting the carrier shaft longitudinally including a longitudinally movable worm engaging the outer end of the carrier shaft, driving connections between grinding shaft and carrier shaft, and resilient means for impelling the shaft outwardly away from the grinding wheel.

Process for making furfural resins. JOHN P. TRICKEY AND CARL S. MINER. U. S. 1,665,233, April 10, 1928. The process of obtaining a resinous substance which comprises treating furfural with a metallic salt that serves as a catalyst for the reaction.

Process for making furfural resins. JOHN P. TRICKEY AND CARL S. MINER. U. S. 1,665,234, April 10, 1928. The process of obtaining a resinous substance which comprises treating furfural with a metal that serves as a catalyst for this reaction.

Furfuralcohol resins. JOHN P. TRICKEY AND CARL S. MINER. U. S. 1,665,235, April 10, 1928. A resinous substance comprising the final substantially infusible and insoluble reaction product of furfuralcohol alone.

Process for obtaining furane derivatives. JOHN P. TRICKEY AND CARL S. MINER. U. S. 1,665,236, April 10, 1928. The process of obtaining furane derivatives which comprises mixing furfural and an alkali in a manner whereby furfuralcohol and a salt of pyromucic acid are produced, and then adding a quantity of an acid sufficient to liberate substantially all of the pyromucic acid and to cause resinification *in situ* of the alcohol when the mixture is heated.

Compound resinous substance and process of making same. JOHN P. TRICKEY AND CARL S. MINER. U. S. 1,665,237, April 10, 1928. (1) The compound resinous reaction

product of a mixture of an alcoholic furane derivative and an aldehydic furane derivative. (2) The process of obtaining a compound resin which comprises subjecting a solution of a plurality of furane derivatives to catalysis, the furane derivatives severally and of themselves being capable of producing by themselves dissimilar resinous reaction products.

Grinding machines. J. E. AND F. S. GEE AND H. C. GAMBELL. Brit. 285,189, April 4, 1928. A grinding or abrading machine consists of a grinding wheel and a rotary work table on which are mounted work-holders automatically opened and closed, means also being provided for feeding the work to the holders and removing it therefrom.

Grinding, crushing, etc. E. C. R. MARKS. Brit. 285,331, April 4, 1928. An abrasive wheel for use in grinding logs into wood pulp comprises a number of abrasive segments mounted upon a rotatable support to which they are secured by means including resilient members to which initial stresses are imparted sufficient to hold the segments under pressure against the support irrespective of any expansion or contraction of the wheel incident with two spring cups engaging and frictionally holding a ball on the underside of the slope.

Guards for Carborundum wheels; removing dust. J. W. WEBB. Brit. 285,341, April 4, 1928. A guard for a Carborundum or like wheel turns on pivots in the framing and is adjusted by a screwed rod engaged by a nut supported on a cross strut in the framing and rotated by a hand-wheel. The wheel is also protected by a box-like guard.

Art

Acid-resisting overglaze colors. R. V. TAILBY. *Jour. Amer. Ceram. Soc.*, **11** [5], 307–309 (1928).—There is great demand for overglaze colors which are resistant to the action of acids and alkalis. Difficulties encountered in the production of such colors are mentioned. Requirements to be met are enumerated. Experimental evidence of acid-resistance is discussed, and a provisional test known as the "immersion test" is described.

Colored glasses. W. M. HAMPTON. *Chem. and Ind.*, **47**, 307 (1928); *Pottery Gaz.*, **53** [610], 642 (1928).—Colored glasses are made under either oxidizing or reducing conditions. No two bases in the glass will give exactly the same tint with any stain in the same atmosphere, but the difference is said to be relatively small unless Na_2O and K_2O are interchanged. The essential difference between oxidized and reduced glasses is that in the former a colored silicate exists, while in the latter the color is due to the scattering of light by ultra-microscopic particles of either the oxide or the element.

H.H.S.

The color of Chinese pottery. R. L. HOBSON. *Illust. London News*, **172**, 217 (1928).—Four colored plates of vases: (1) an apple-green glaze and a stone-gray crackle, (2) a turquoise blue, (3) a buff stoneware with opalescent lavender-blue glaze, and (4) a porcelain with colored glazes and belts of engraved designs. H.H.S.

Recent discoveries in India. I. JOHN MARSHALL. *Illust. London News*, **172**, 477 (1928).—In a former series of illustrated articles (see *Ceram. Abs.*, **7** [4], 206 (1928)) M., director-general of archaeology in India, described the prehistoric remains, dating from the 3rd and 4th millennia B.C. at Mohenjo-daro and Harappa in Sind and the Punjab. In the present new series he leaps 20 centuries to 300 B.C. The photographs are of Pataliputra, in Bihar, near the modern Patna. They include two terra cotta figurines, one of a dancing girl with a reel-like object for expanding her ear-lobe.

H.H.S.

Recent discoveries in India. II. Taxila. JOHN MARSHALL. *Illust. London News*, **172**, 522–23 (1928).—M. describes a remarkable *cache* which he thinks to be the spoil of ancient burglaries, of gold, silver, and pottery ornaments at Taxila in the north of the

Punjab. There were 8 cities at Taxila, ranging in date from 700 B.C. to 500 A.D. The *cache* was found at the back of a Buddhist Temple. Some of the vessels were inscribed with the names of their owners, and it is by the variety of these names that it is surmised that the treasure was stolen property (but perhaps temple offerings). A terra cotta female head shows Greek influence. H.H.S.

Pottery finds in Macedonia. A. M. WOODWARD AND W. A. HEURTLEY. *Morning Post*, March 13, 1928.—An account of the 1927 work of the British Archaeological School at Athens, of which school the authors are the directors. At Boubousta, in western Macedonia, the pottery found indicates that the settlement dates from 1500 B.C. and that its inhabitants were originally Anatolian, but spoke Greek. The finds include a statuette of a female, a lion, the head of a boar, and a head adorned with a large wig like those worn in Stuart times in England. Excavations are now proceeding at Olynthos in south Macedonia. H.H.S.

Palestine arts and crafts. ANON. *Morning Post*, March 17, 1928.—For the first time Jerusalem has witnessed a representative exhibition of the arts and crafts of the Holy Land. The pottery, jewelry, Galilean marble, and other ware are of peasant workmanship, and are similar to such goods in the Canaan of the Bronze Age. An interesting set of exhibits came from the workshops which are restoring that gem of architecture, the Dome of the Rock. H.H.S.

Stained glass of the future. MEINHOF. *Diamant*, **49** [22], 424–25 (1927).—A discussion of the work of Paul Schmunde of Halle a. Sa., who is not only an artist but also a scientist, producing stained glass of considerable merit. E.J.V.

Glass staining in the Middle Ages and Renaissance. JOHN A. KNOWLES. *Diamant*, **49** [22], 428–30; [24], 464–68; [25], 482–85; [26], 508–509; [27], 533–34; [28], 549–50; [29], 576–78; [30], 592–94; [32], 632–34 (1927).—A very comprehensive review and compendium of information on glass staining in the Middle Ages and during the Renaissance, extracted from writing contemporaneous to those periods. E.J.V.

Michael Sigismund Frank. F. X. ZETTLER. *Diamant*, **49** [33], 646–48 (1927).—A discussion of the lives and works of different German artists in stained glass. Michael Sigismund Frank, born in 1770, was called the reviver of German stained glass art. His life and works are taken up in detail. E.J.V.

Liquid gold production in Russia ANON. *Pottery Gaz.*, **53** [610], 662 (1928).—The Russian ceramic industries have not produced liquid gold and up to the present time it has been imported from Germany. In 1918 the question of its production was discussed. A special plant was installed in February, 1927, and great technical difficulties have been encountered in the process of production. E.J.V.

Recent accessions of the classical department. GISELA M. A. RICHTER. *Bull. Met. Mus. Art*, **23** [3], 78–82 (1928).—The Classical Dept. has recently acquired a number of small objects of high excellence, exhibited this month in the Room of Recent Accessions. Besides several distinguished bronzes there are: (1) Three newly acquired terra cotta statuettes. (*a*) One is a seated deity of primitive type designed for front view; the body is flat like a board, the face carefully modeled. There are remains of red, yellow, and black on a white engobe to indicate the pattern on the garment. This comes from the Schliemann collection. (*b*) A graceful Tanagra statuette is of a girl dressed in chiton and himation. An attempt is made to show some of the folds of the chiton through the himation, a style of drapery in vogue in marble sculptures during the 2nd Century B.C. A statuette similar except for the head is in the British Museum. (*c*) Another statuette is of a girl with only stumps for arms and legs, evidently a doll intended to be dressed by a child. A tiny oinochoë was also once a child's toy. On it is painted by a delicate hand a Nike drawing, a four-horse chariot in red-figured technique of 5th or 4th Century B.C. A large pomegranate probably served as an

offering at a shrine and was once painted a vivid red. (2) Three antefixes from roofs of buildings are examples of architectural terra cottas. All three are of the archaic period; two represent masks of the fearsome Medusa and one that of a satyr crowned with garland of ivy leaves. (3) The "Millefiori" bowls are among the most precious of the ancient glass industry. Three examples are now added to the Museum's collection. One in perfect condition has a flower pattern in green, white, red, and yellow mosaic against a dark blue background, and a red and black rim. Another has triangles of yellow, green, blue, and white glass in effective combinations. A third has a criss-cross pattern of yellow, white, green, and purple bands. There are also two fragments, one a piece of mosaic glass with charming design of flowers, the other a "cameo" glass with the upper part of a young satyr beautifully carved in opaque white against a translucent blue. A.A.A.

Ceramics in Berlin museums. OTTO RIEDRICH. *Keram. Rund.*, **36,** 8–11 (1928).—The paper includes photographs of ceramic museum pieces. H.I.

Ceramic art in 1927. MAX SCHNEIDER. *Keram. Rund.*, **36,** 27–29 (1928).—The adherence to the old and the lack of modern motifs in German ceramic art are criticized. H.I.

Studies in glass and ceramics. E. PAZAUREK. *Keram. Rund.*, **36,** 32–33 (1928).—A series of papers on ceramic art is announced. H.I.

Coloring glass with arsenious oxide. ANON. *Ceram. Ind.*, **10** [4], 403 (1928).—The coloring action of arsenious oxide (5–25%) on glasses of the type $1.3R_2O \cdot RO \cdot 6SiO_2$ and $R_2O \cdot B_2O_3 \cdot 6SiO_2$ has been investigated. A large amount (15%) of arsenious oxide produced opalescence on melting or on reheating. Glasses containing arsenious oxide, particularly potash glasses, are reduced by the action of a flame the surface being colored brown. F.P.H.

Colors for ceramics. ANON. *Farben-Ztg.*, **32,** 2599–600 (1927).—Formulas for colors used for china painting are given. (*C. A.*)

Brilliant gold. F. CHEMNITIUS. *Jour. prakt. Chem.*, **117,** 245–61 (1927).—A review of the different methods of preparing the different solutions entering in the preparation of brilliant gold for the gilding of porcelain, glass, or stoneware. (*C. A.*)

Some coloring agents in glasses and glazes. ROBERT ROBERTSON AND HERBERT JACKSON. *Proc. Royal Inst. Great Brit.*, **25,** 230–41 (1927).—The characteristics and uses of Cu, Cu oxides, and Fe oxides as coloring agents are described. Since the color produced by metals and metallic oxides in the glass is determined by the particle form and size of these components, the temperature to which the glass is heated, oxidation conditions, and rate of cooling affect the shades produced. When glass containing CuO is heated under reducing conditions, black results in place of olive-green tints. The yellow tint produced by Fe_2O_3 in flint glasses deepens with lower alkali content. It is suggested that the color of lapis lazuli is due to finely divided Fe_2O_3 in suspension. Tints produced in glass by radiations can usually be destroyed by heating, with the exception of glasses colored by Fe_2O_3 and MnO_2. Minerals, as amethystine quartz, decolorize on heating but regain their tints on exposure to γ-rays. Untinted quartz is unaffected by these rays. (*C. A.*)

PATENTS

Method and means for producing hand-made tile. JOHN R. WARFIELD. U. S. 1,663,106, March 20, 1928. In an apparatus for forming hand-made clay tile, the combination of a base, a core removably supported on the base, retaining plates secured to the base, a cutting element, and means secured to the base for actuating the cutting element to cut the surplus clay from a billet of clay kneaded on the core.

Pottery-making method. ALBERT E. RADFORD. U. S. 1,665,978, April 10, 1928. A method of decorating pottery consisting in kneading together a plurality of masses

of plastic clay to effect a streaked mass in which the colors are still distinct, detaching part of the kneaded mass, applying to an absorbent mold, distributing to a smooth film, repeating the operation until a desired film is obtained, applying a slip to increase the wall thickness, drying to free from the mold, and firing, whereby when fired a mottled effect of any desired fineness of grain may be effected.

Cement, Lime, and Plaster

"True" density of limestones in the manufacture of lime. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, p. 32 (1928).—The density, porosity, and crystal size of limestones are being studied at the Bureau of Standards with a view to improving the manufacture of lime products. It is hoped that the careful determination of these properties may give some index as to the optimum conditions to be imposed upon stones of different types in order to yield the most satisfactory products. Density determinations and the method followed in determining them are given for 12 samples of stones procured from widely scattered sections of the country. The "true" density values vary from 2.383 to 2.882. R.A.H.

X-ray study of magnesium oxychloride cement. Inst. Phys. Chem., Tokyo, *Sci. Papers*, **5**, 95–102 (1926); *Rock Prod.*, **31** [6], 101 (1928).—An X-ray study of powdered magnesium oxychloride cements shows the presence of crystalline $3MgO \cdot MgCl_2 \cdot 12H_2O$ in the cement after setting. Magnesium hydroxide together with magnesium chloride solution yields a product in which definite crystalline structure could not be found, although it appears possible that imperfect crystals might be present. The diffraction lines of magnesium oxide cannot be found in the diffraction diagram of hardened cement. The presence of crystals in the cement is not, however, a confirmation of Le Chatelier's theory (*Trans. Faraday Soc.*, **14**, 8 (1919)), as these crystals may be of the dimensions of colloidal particles. F.P.H.

Lime in Portland cement compounds. W. C. HANSEN AND R. H. BOGUE. *Rock Prod.*, **31** [5], 46–50 (1928).—See *Ceram. Abs.*, **7** [1], 9 (1928). F.P.H.

Evolution of the gypsum wallboard. JOSEPH ROSSMANN. *Rock Prod.*, **31** [5], 51–55 (1928).—A review is made of American patent literature on gypsum wallboard manufacturing processes and types. F.P.H.

Changes undergone by cement in the kiln. ALTON J. BLANK AND W. B. WILLIAMS. *Rock Prod.*, **31** [6], 74–76 (1928).—Graphs are presented showing analyses of materials at different positions along the length of the kiln. F.P.H.

Modern New England gypsum plant. H. J. BROWN. *Rock Prod.*, **31** [6], 77–82 (1928).—A description is given of the plant of the Atlantic Gypsum Products Corp. at Portsmouth, N. H. The first pneumatic conveyer for raw and calcined gypsum ever installed for this purpose is in use at this plant. F.P.H.

Modern German automatic shaft kilns. ANON. *Tonind. Ztg.*, **51** [65], 1145–48 (1927); *Rock Prod.*, **31** [5], 80 (1928).—Great improvements are claimed for the Mannstaedt kiln manufactured by the Klockner Werke A. G. in Troisdorf, which is said to be adaptable for the cement industry as well. Essentially the advantages are said to consist of: (1) uniform air distribution throughout the kiln due to central admission of air under the grate; (2) admission of the combustion air at high pressure permits reaching the required high temperatures most economically; (3) completely airtight discharge of the burned dolomite without pressure variations or change in the temperature of the kiln; (4) uniform operation of the roller grates of the grate over the entire cross-section, causing no accumulations in the sintering zone; (5) no crushing of the burned dolomite by the rollers to cause excessive fines in the dolomite; the finished product corresponds to the size desired or to the clearance between rollers; (6) substantial construction, no sensitive parts, bearings, or supports inside the kiln; the only parts located in the interior are the heavy, slowly revolving cast-iron rollers. F.P.H.

Soluble silica and magnesia cements. ANON. *Tonind. Ztg.*, **51** [100], 1812–13 (1927); *Rock Prod.*, **31** [5], 80 (1928).—Silica in its soluble form is used to improve the density in magnesia cement. Tests show that with increasing concentration of the caustic solution, the silica admixture gives reduced elongation changes, whereas precipitated silicic acid increases this effect. As precipitated silicic acid is capable of increasing the density of magnesite, but with effect not as marked as that of silica, the conclusion is drawn that silica possesses special properties which are not entirely of chemical nature, but rather of the physical-chemical origin. F.P.H.

Setting and hardening of cements. R. NACKEN. *Zement*, **16**, 1017–24, 1047–51 (1927); *Rock Prod.*, **31** [5], 80–81 (1928).—N. after a thorough X-ray study of the constitution of cements confirms his joint researches with W. Dyckerhoff that dicalcium silicate in a metastable form is the carrier of the properties of Portland cement. F.P.H.

Resistance of cement to aggressive solutions. ANON. *Zement*, **16**, 1190–92 (1927); *Rock Prod.*, **31** [5], 80 (1928).—All acids are destructive to concrete; all bases are without effect and salts are partly destructive and partly harmless. Only inorganic salts soluble in water have a detrimental effect, particularly the sulphates of calcium, magnesium, sodium, potassium, and ammonium and also the chlorides of magnesium and ammonium. Dense concrete and a protective coating are the best guarantees of resistance to such aggressive action. Portland cements with high silica or high iron oxide cement and low alumina content are resistant cements even when low in lime. Portland cements with average silica, alumina, and iron oxide content must have a hydraulic modulus not greater than 2.0. Higher alumina Portland cements (8–9%) may be advantageously mixed with trass. The lime content alone is no criterion of the resistance of a cement to aggressive solutions. F.P.H.

Hardening of plaster of Paris and the existence of soluble anhydrite. P. P. BUDNIKOFF. *Kolloid Zeit.*, **42**, 149–54 (1927).—The crystallization of $CaSO_4 \cdot 2H_2O$ from $CaSO_4 \cdot {}^1/_2H_2O$ by the addition of water was observed microscopically. B. concludes that there is an intermediate colloidal stage. The formation of soluble anhydrite was attempted by mixing an anhydrous methyl alcohol solution of H_2SO_4 with an anhydrous methyl alcohol solution of $CaCl_2$. The calcium sulphate was in the form of a colloidal precipitate which showed an ignition loss of 7–9% after drying at 38°C. The synthetic product was more readily soluble than natural anhydrite. B. concludes that the question of the existence of soluble anhydrite is still unsolved. H.I.

Cement factory in Bolivia. ANON. *Chem. and Ind.*, **47**, 316 (1928).—Production has now begun at the first cement factory to be established in Bolivia. The output at present is 150 barrels a day, but double this amount is expected in a year. H.H.S.

Magnesite in 1927. EDITORIAL. *Eng. and Min. Jour.*, **125** [3], 107 (1928).—On the whole, domestic production of caustic calcined magnesite was less than in 1926. Importations were about 10,000 T. A.J.M.

Lime kiln. H. E. SCHMIDT. *Eng. and Min. Jour.*, **125** [5], 213 (1928).—A sectional detail of the kiln is given. A.J.M.

Pozzuolanas. A. D. COWPER AND F. L. BRADY. Dept. Sci. Ind. Research, *Building Research* (Brit.) *Bull.*, No. **2**, 10 pp. (1927).—A general description of natural and artificial pozzuolanas. (*C. A.*)

BOOK

The Concrete Year Book, 1928. Published by Concrete Publications, Ltd., 20 Dartmouth St., Westminster, S.W. 1, England. Price 3/6 net. L.P.C.

PATENTS

Acid-proof cements. I. G. FARBENINDUSTRIE AKT.-GES. Brit. 283,471, March 7, 1928. An acid-proof cement composition comprises water-glass solution to which has

been added a powder containing substances having a strong capacity for combining with alkali. Examples of suitable substances are tungstic acid, salts of fluorozirconic, fluorogermanic, fluoric, fluorotitanic, fluorotantalic, fluoroniobic, and fluorostannic acids, silicon, silicon alloys, silicofluorides, cryolite, and aluminium. Small quantities of 2–4% of these substances are added to mixtures containing quartz sand to form a powder for mixing with water-glass.

Colored cement or cement mixtures. Brit. 280,813; *Rock Prod.*, **31** [6], 101 (1928).—The components of cement plaster, gypsum, etc., are ground together with coloring matter in a mill adapted to reduce them to an extremely fine state, the fine particles being drawn off by air-flotation under a vacuum. Sodium silicate or other waterproofing powder is added. F.P.H.

Waterproofing cement products. Brit. 281,022; *Rock Prod.*, **31** [6], 101 (1928).—Cement products are treated with a composition of 1 part by weight of boiled shellac dissolved in alcohol, acetic acid, or caustic alkali, and 8 parts by weight of alum boiled with water to a thick liquid, the ingredients being mixed to form a thin paste, and sufficient water is added to carry the mixture into the pores of the concrete. F.P.H.

Porous cement products. French 606,042; *Rock Prod.*, **31** [5], 81 (1928).—Tiles or sheets of material suitable for use as insulators against heat and sound are prepared from mixtures containing colloidal solutions worked up to a froth with cement, gypsum, etc. The colloidal solutions are prepared, *e.g.*, by vigorously stirring mixtures of solutions in alcohol or acetone of resins, cellulose esters, phenol-formaldehyde condensation products, rubber, etc., with solutions containing formaldehyde and such substances as glue, casein, dextrin, starch, etc. Frothing can be improved by the addition of saponin, soap, etc. F.P.H.

Treatment of hydraulic cement. French 619,346; *Rock Prod.*, **31** [6], 101 (1928).—The setting time and hardness of the product are regulated by adding rare earths, a compound of an element of the fourth group of the periodic system, *e.g.*, 0.3% titanic oxide, and, if desired other material, such as calcium sulphate, to lime or cement. F.P.H.

Calciner for cement. Ger. 444,569; *Rock Prod.*, **31** [6], 101 (1928).—The finely-divided materials combined with gaseous, liquid, or pulverized fuel and preheated combustion air are injected downward or in a horizontal direction into a combustion chamber. The chamber is located below a steam boiler and the final product is withdrawn at the bottom between cooling tubes. F.P.H.

Calcining cement and lime in a shaft kiln. Ger. 445,014; *Rock Prod.*, **31** [6], 101 (1928).—The finely divided material, alone or mixed with coal dust, is charged tangentially through tubular opening into the upper part of a shaft furnace in which it is brought in contact with a counter-current of hot gases. F.P.H.

Enamels

Thermal expansion of "stainless" iron alloys. PETER HIDNERT AND W. T. SWEENEY. Bur. Stand., *Sci. Paper*, No. 570, 9 pp. (1928).—Data on the physical properties of low-carbon iron chromium alloys of the stainless iron type are desirable, because these alloys are being used to an increasing extent for various purposes, such as turbines, devices for handling acids, and the manufacture of other articles that resist corrosion. The investigation was undertaken because no data on the thermal expansion of stainless iron were available. The paper gives results on the linear thermal expansion of 9 samples of stainless iron which were obtained from various sources. The chromium content of these samples varied from 11.9 to 16.4% and the carbon content from 0.09 to 0.13%. Expansion determinations were made over various temperature ranges between room temperature and 1000°C. Transformation regions were located

on some of the samples. The expansion curves of all the samples are shown and discussed. The data relating to the critical regions indicate that an increase in the chromium content of stainless iron generally causes a slight increase in the temperature at which transformation occurs on heating. The contraction during the transformation on heating decreases with increase in chromium content. The table in the summary gives average coefficients of expansion derived from data on all samples of stainless iron. The coefficient of expansion increases gradually with temperature. Curves showing a comparison of the expansion of stainless iron and pure iron are shown. R.A.H.

Wall tile from sheet steel. ANON. *Ceram. Age*, **11** [3], 117–118 (1928).—The tile are pressed out of sheet steel to form oblong, panlike units of the same frontal dimensions as regular ceramic wall tile. Each tile is set individually in a cement covered insulating base slab of composition material. The enameled tile make possible the fullest gratification of the desire for color. They can be applied directly over existing walls. Their cost is about one-half that of regular ceramic tile. A.E.R.W.

Continuous enameling furnace economical in operation. ANON. *Fuels and Fur.*, **6** [2], 231–32 (1928).—A description is given of a continuous enameling furnace installation which is 119 ft. long and contains a furnace 60 ft. long. The ground and finish coats are both fired in this unit and drying is also carried out. Temperatures, heat gradients, and heating periods are automatically controlled. A chain conveyer is used which is suspended above the furnace by a steel framework. The furnace is divided longitudinally into 5 zones, 2 preheating, 2 drying, and 1 firing zone. A semimuffle divides the heating zone laterally into 2 compartments which are maintained at different temperatures, one for ground coats and the other for finish coats. Ware is loaded and unloaded at both ends of the kiln continuously. A vigorous transfer of heat is obtained between the cooling and the heating ware. Sixteen manifolded, automatically controlled gas burners are used. An oxidizing neutral or reducing condition can be maintained in the furnace automatically. Loss of heat from the slots in the roof is prevented by hoods in which a balancing air pressure is produced. The ware is heated in 7 min., and the same enamels are used on all weights of ware, 20 to 24 gage being run simultaneously. A.E.R.W.

Preparation and manufacture of sheets for enameling. ANON. *Fuels and Fur.*, **6** [2], 243–44 (1928).—Improvement in base metals has reduced cull loss and yielded a better enameled product. For sheet metal the enameler has the choice of ingot iron or steel. For the great majority of work, ingot iron is preferable to steel because it is commercially pure iron, is free from solid and gaseous impurities, lies flat at enameling furnace temperatures and is readily welded. It may now be secured in 26 gage. If ordinary steel sheets are used in place of specially prepared sheets, several difficulties are encountered; these are listed. In the manufacture of the ingot iron care is taken to eliminate gases and to produce a uniform structure. Proper annealing is very important. Pure iron is extremely workable and therefore suitable for deep drawing. Properly made welds of pure iron have proved as strong and durable as the surrounding material itself. Photographs show welding lines and shock lines in enamel fired on steel. A.E.R.W.

Corrosion at the contacts of dissimilar metals. U. R. EVANS. *Chem. and Ind.*, **47T**, 73–77 (1928).—Corrosion of steel half immersed in NaCl solution is greatly increased by contact with copper, the increase depending on the width of the copper contact. Nickel produces less effect, and Pb still less. The corrosion is less marked in a hard water than in the salt solution. Zinc affords complete protection to the steel in most liquids, but it is itself sacrificed in solutions of Na salts, though not in waters containing Ca salts. Potential measurements indicate that Cu and Ni are cathodic to steel, Zn and Cd are anodic, while Sn, Pb, and Al are variable. H.H.S.

Safeguarding of hollow-ware industry. ANON. *Chem. and Ind.*, **47**, 326 (1928).—A committee has been appointed by the British Government under the Safeguarding of Industries Act to inquire into the present position of the enameled hollow-ware industry, and to report whether it is or is not such as to justify the imposition of a duty (and, if so, what duty) on imported articles. H.H.S.

Impact resistance of castings. R. W. MOFFATT. Nat. Res. Council Canada, *Annual Report* **10**, 94–95 (1928).—Resistance to impact at ordinary room temperatures of castings of electric furnace cast iron, high-silicon cast iron, and ordinary cupola cast iron is very low, being 2–6 ft. lbs. per sq. in. At −4°F it is so low that the results were not recorded. Steel castings were stronger, the resistance being 182 ft. lbs. for electric furnace steel at room temperature and 100 at −4°. H.H.S.

Enamel technology and enamel science in 1927. W. FISCHER. *Keram. Rund.*, **36**, 1–5 (1928).—The literature is reviewed and a bibliography of 70 titles is included. H.I.

Automatically controlled conveyers in an enameling plant. ANON. *Iron Age*, **121** [4], 264–67 (1928).—A complete description of the plant of the Louisville Enameled Products Co., Louisville, Ky. is given. A plant layout diagram is given. The plant has several unusual features. (Illustrated.) A.J.M.

PATENTS

Method of making sheet-metal articles. ROBERT V. PROCTOR. U. S. 1,663,316, March 20, 1928. The method of manufacturing sheet metal articles comprising forming a blank, shaping it to produce a plurality of corrugations, subjecting the corrugations to pressure to cause the metal therein to flow into one fold and compressing the fold.

Pickling machine. CONSTANTINE G. MILLER AND CHARLES F. CLEVELAND. U. S. 1,664,428, April 3, 1928. In an automatic pickling machine of the class described, the combination with a framework, article carrying means movably mounted thereon, mechanisms for operating the article carrying means, a stationary platform positioned to permit the article carrying means to pass therethrough to permit articles thereon to be deposited on the platform, and rotatable means operating through the platform adapted to discharge the articles therefrom.

Glass

Some effects of carefully annealing optical glass. L. W. TILTON, A. N. FINN, AND A. Q. TOOL. *Jour. Amer. Ceram. Soc.*, **11** [5], 292–95 (1928).—The apparent lack of optical homogeneity in good optical glass may be the result of small differences in temperature during annealing. That this can be eliminated to a large extent by careful furnace control has been demonstrated. Furthermore, this may be done without appreciable change in the average index of refraction if the "thermo-optical" constants of the glass are predetermined.

Casting a disk for a telescope reflector. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, p. 35 (1928).—A description of the mold used in connection with the casting of a disk for a telescope reflector and the system followed in cooling the glass from 1000°C to ordinary temperatures. R.A.H.

The increasing use of feldspar in glass. VICTOR V. KELSEY. *Amer. Glass Rev.*, **47** [26], 15–16 (1928).—The rôle of feldspar in the glass batch is discussed. It is considered good practice to begin by using approximately 10 lbs. of feldspar to 1000 lbs. of glass sand and gradually increasing the amount of feldspar at the rate of approximately 5–10 lbs. per day to each 1000 lbs. of sand until about 100 lbs. of feldspar is being used to 1000 lbs. of sand. The use of feldspar in glass batches is growing rapidly and has been adopted by the leading glass manufacturers of this country.

Glazed cities in the "Age of Glass." WILLIAM L. BAILEY. *Amer. Glass Rev.*, **47** [27], 27–28 (1928).—This age is called the "Age of Glass." The evolution of building is outlined from the time of the windowless cave to the modern cities described as "windowed." B. says that the window is one of the most distinguished marks of modern civilization.

Link new type leer with recuperator tank for glassware production. ANON. *Ceram. Ind.*, **10** [4], 402–403 (1928).—The Carr-Lowrey Glass Co., Baltimore, Md., has a new type leer, which is handling the output of 18 shops and three hand presses. All sizes and shapes up to 64-ounce containers are being annealed. Three different colored glasses can be handled at one time. Initial temperature in the front of the leer is 975°F and all ware is annealed in 2 hours. The temperature control of this leer is unique in that it provides for the removal of waste heat at intervals throughout the length of the leer, thus permitting perfect control of temperature gradient. For annealing the output of 18 shops and 3 hand presses, 85 gallons of oil are required every 24 hours. It is estimated that the cost of fuel per ton of annealing ware is about 8 cents. The apron is a special alloy metal woven chain, and the drive is accomplished by a 2 H.P. motor mounted on the leer frame. The pulley of the leer is of rubber, giving a combination of practically perfect friction and extraordinary wearing quality. F.P.H.

Cost computation in glass plants. MARK M. COVERT. *Ceram. Ind.*, **10** [4], 404–10 (1928).—The need for adequate cost systems is stressed. The manufacture of glass products lends itself readily to the following departmental divisions: (1) tanks, (2) leers, (3) shop labor, (4) trimming, (5) packing and shipping, (6) administrative. F.P.H.

Barytes for glass. ANON. *Ceram. Ind.*, **10** [4], 411 (1928).—Barytes, a natural mineral ($BaSO_4$), is reported to have the following characteristics valuable to the glass manufacturer. It is a cheap natural mineral, although the present market prices are relatively high considering its value. It is claimed that barytes cuts down breakage and eliminates seeds. It is an active flux, lowering the melting point of the batch considerably. Very few glass manufacturers are using barytes at present because so little is known of its properties and how to use it and there is a trick in the latter. A few leading glass-container manufacturers, however, are reported to be using it but any attempt to get information about its use is met with evasion. F.P.H.

Lighting of the future. ANON. *Ceram. Ind.*, **10** [4], 414–15 (1928).—Fixtures and lamps selected in Paris as representative of the present trend in French lighting equipment are illustrated. F.P.H.

Effect of combustion conditions on glass-furnace operation. D. J. MCSWINEY. *Fuels and Fur.*, **6** [2], 171–74 (1928).—Although the waste gas is the factor to which attention is first directed in improving the heat efficiency of other types of furnaces, little attention is usually given to obtaining balanced combustion in the average glass furnace. McS. points out a number of reasons why this condition exists, (1) the inability to control the fuel-air ratio in the incoming gases, and (2) the fact that the combustion conditions have a marked effect on glass quality. The effect of stack draft on the refiner temperature and waste-gas composition for a typical furnace is shown by a table. The sensitiveness of manganese to flame conditions has caused the almost complete substitution of selenium for manganese in the decolorization of glass. The waste gas compositions are different for different ports in a tank and an attempt to balance combustion based on gas analyses from one port may have harmful results. The intake of air can be greatly influenced by the resistance or aid offered by the pressure obtaining in the tank. The effect of checker capacity and variations in the conditions in the regenerators is discussed. A variation in waste-gas composition results from the evolution of CO_2 and other gases from the batch during melting. This affects the composition of the gases at the rear port more than at the other ports. The possible fuel saving

by uniform combustion is sufficient to warrant accurate measurement, and closer control. The stack draft should not be used for varying the temperature of the working end of the tank. This should be done by varying the height of the bridge or shadow wall. A.E.R.W.

Effect of heat treatment on physical properties of glass. A. Q. Tool and D. B. Lloyd. *Fuels and Fur.*, **6** [3], 353–56 (1928).—During the annealing of a glass, stress relaxation and physico-chemical reactions are allowed to proceed further toward completion. The latter phenomena result in changes in the physical properties of the glass, such as density, refractivity, and thermal expansion. Quick cooling prevents the occurrence of both groups of phenomena. When the annealing temperatures are high the reactions proceed rapidly. By holding the temperature constant for a sufficient length of time, equilibrium can be obtained. If the glass is cooled too quickly for equilibrium to be reached at each temperature, the temperatures through which it is cooled are called the "effective treating temperatures." Electrical conductivity, color, and transmission are also affected by the heat treatment. Changes in strength and hardness are masked by the relaxations of strain. If the effective treating temperature is high in the annealing range, less dense glasses are produced than by slow cooling. Changes in density due to heat treatment are often greater than 1%, and are sufficient to account for changes in the ice-point of thermometers used at different temperatures. They may also produce stresses in ordinary glassware and have a possible bearing on some of the difficulties met in glazes and enamels. In annealing optical glass, even small temperature gradients may cause large refractivity variations necessitating surface retouching, and may exist when all harmful strain is absent. The variations in refractivity in most glasses lie between 2 and 5 in the fifth decimal place for each degree C change in the effective annealing temperature. The rate of approach to equilibrium doubles for 5–15°C temperature increments. A.E.R.W.

Improvements in glass furnaces. Anon. *Fuels and Fur.*, **6** [3], 369–70 (1928).—An account is given of the discussion of the design and operation of glass furnaces which took place at the first 1928 meeting of the Society of Glass Technology in England. Important topics were the refining of glass and the manufacture and use of glasshouse pots. A.E.R.W.

Ventilating glass houses. Gutman. *Diamant*, **49** [17], 321–24 (1927).—A description of methods which can be used to ventilate the working rooms in glass factories, illustrated by sketches and diagrams. E.J.V.

Removal of mat spots from glasses. Anon. *Diamant*, **49** [17], 329–30 (1927).—A discussion of the methods and materials used for removing dull spots from glass surfaces by treatment with chemicals or by polishing with various compounds. E.J.V.

The production of glass window ventilators. P. M. *Diamant*, **49** [18], 345–46 (1927).—A description of the types and methods of making glass window ventilators. E.J.V.

Quartz glass as window glass. Franz Woas. *Diamant*, **49** [19], 361–62 (1927).—A discussion of the use of quartz glass as a window glass, considering its transmission of ultra-violet rays, its cost, workability, and stability. E.J.V.

Stability of silvered mirrors. Max Ermes. *Diamant*, **49** [19], 372–73 (1927). E.J.V.

Glass defects. Anon. *Diamant*, **49** [19], 368–70; [20], 384–85 (1927).—A discussion of the production of glass and defects which occur therein. Two kinds of defects are real and unreal. The defects discussed include limey glass, the burning through of colors, devitrification, etc. E.J.V.

Illumination of machine and work shops. ANON. *Diamant*, **49** [20], 389–90 (1927). —A discussion of the use of modern lighting fixtures and reflectors for illumination in shops and the effect on increasing production. The different types of reflectors are described and discussed. E.J.V.

Mechanical arrangement for cutting and taking apart glass rods and tubing. T. J. K. *Diamant*, **49** [21], 403–404 (1927).—A description of a new mechanism produced by Schonenberg and Anninga, Eindhoven, Holland, for cutting glass rods and tubing. E.J.V.

Quartz glass as window glass. E. ZIMPELMANN. *Diamant*, **49** [23], 449–50 (1927). —A discussion of the properties of quartz glass which make it of value as a window glass, especially its therapeutic value due to transmission of ultraviolet rays, its stability, etc. E.J.V.

Mirror silvering in perfection. MAX ERMES. *Diamant*, **49** [25], 488–89 (1927).—A discussion of the development of the process of silvering mirrors, starting with its discovery by Liebig in 1835, and tracing its improvement by later workers until it is now perfected. E.J.V.

Corroding of glass to improve surfaces. M. P. *Diamant*, **49** [28], 548 (1927).—This is not a process for etching glass with acids, etc., but deals with the production of definite color tones by the application of metallic compounds. The method is described in detail and compounds and mixtures used for producing various colors are listed. E.J.V.

Fourcault plate glass drawing process. ANON. *Diamant*, **49** [29], 572–74; [30], 585–589; [36], 705–708 (1927).—A complete description of the Fourcault process, tracing the improvements as patented. E.J.V.

History of Saint-Gobain Plate Glass Company. ANON. *Glass Ind.*, **9** [4], 75–78 (1928).—The history of the Saint-Gobain Plate Glass Co. (Manufactures des Glaces et Produits Chimiques de Saint-Gobain et Cirey) is of interest to the American glass manufacturer, since it shows the development through a period of 263 years of what is now one of the most powerful organizations in the world devoted to glass manufacture in its different branches. The recent establishment of the Blue Ridge Glass Corp's. plant by this concern at Kingsport, Tenn., in combination with the Corning Glass Works and the Belgian National Glass Works has served to increase the importance of this organization to the American glass industry. E.J.V.

The breaking strength of the glasses as a function of the composition. OSCAR KNAPP. *Glass Ind.*, **9** [4], 78–80 (1928); translated from *Glas-Ind.*, **35**, 245–47 (1927).—The first investigators who studied the fracture condition in glasses from the viewpoint of actual practice were Winkelmann and Schott, who took up the behavior of glasses under sudden changes in temperature, the so-called thermal impact. Starting from certain theoretical assumptions, they set up the following relation: $W = \frac{P}{a \cdot E} = \sqrt{\frac{k}{s \cdot c}}$, where W = thermal strength, P = tensile strength, a = expansion, E = elasticity, k = thermal conductivity, s = sp. gr., and c = sp. heat. To confirm the correctness of this formula, Winkelmann and Schott made polished cubes from the glasses investigated, heated them in water (or if temperatures above 100°C were necessary, in glycerine) and after reaching the desired temperature, suddenly cooled them to room temperature by dipping them into cold water. The temperature differences withstood by the samples without breaking were determined. The results which were obtained with cubes 1 cm. on an edge are given in Table I, with information on the value, T, of the temperature differences, and the thermal strengths, W.

TABLE I

No.	Glass	W	T	log T
1	W 20	3.5	61.9	1.79
2	W 27	4.3	62.7	1.80
3	W 33	5.9	87.0	1.94
4	W 26	6.4	88.5	1.95
5	W 28	7.0	88.4	1.95
6	W 24	7.5	98.5	1.99
7	W 13	7.5	50.5	1.71
8	W 23	8.4	90.5	1.96
9	W 25	9.7	103.5	2.01
10	W 22	10.4	103.5	2.01
11	W 34	12.2	148.0	2.17
12	W 21	12.3	148.0	2.17

A practical test taken up officially in America, was worked out by the Bureau of Standards in Washington. Beakers made of the glass under investigation are filled with 200 cc. of melted paraffin and then heated until the paraffin has a temperature of 215°. With constant stirring the temperature is reduced to 200° and the beaker immersed rapidly in ice-water. The number of resultant fractures is given in per cent. With heat-resistant glasses the results tabulated in Table II were obtained, in which B is the percentage fracture. The Bureau of Standards has worked out a dropping test in order to be able to observe the fractures on falling. Beakers of different composition but the same size are allowed to drop with the bottom down on a board 3.8 cm. thick from a height increasing from 12.7 cm. until fracture results or until a height of 104 cm. is reached without fracture. In these investigations the stress conditions are also observed. Of all the data obtained, only that for the slightly stressed glasses and glasses in which the stress has been removed has been considered, and the dropping heights which many times differed very greatly have been averaged. The values are given in Table II where h is the dropping height.

TABLE II

No.	Glass	W	B	log B	h	log h
13	Kavalier	10.1	50	1.70	12.7	1.10
14	Nonsol	10.2	20	1.30	25.4	1.40
15	Fry	11.0	42	1.62	43.2	1.64
16	M. E. G. & Co.	11.8	40	1.60	19.1	1.28
17	Jena	14.5	30	1.48	25.4	1.40
18	Libbey	15.5	17	1.23	25.4	1.40
19	Pyrex	28.7	10	1.00	59.2	1.77

In order to be able to reach a conclusion as to the breaking strength, K has assumed that of the different mechanical properties that play a part in dropping and in impact, the tensile strength, the elasticity, and the expansion are important and that on the other hand, the thermal properties and the specific gravity do not have much influence worth mentioning. In order to confirm or contradict this assumption he has calculated the values: $S=\frac{P}{a \cdot E}$ where S=impact strength, and compared the values obtained with the dropping heights or the logarithmic values of the dropping heights. A diagram obtained on the basis of Table III shows that the existence of a uniformity can be stated although one glass differs from another.

As is clear from the calculation of the value $\sqrt{\frac{k}{s \cdot c}}$ there are only slight variations with the glasses of different compositions. In the case of the heat-resistant glasses these amount to only 0.0059 to 0.0068. The figures of the impact strength therefore are only changed a little when we multiply them by these values. In other words, this means that the Winkelmann thermal strength formula also holds for the impact by falling. The relation between the values W and the dropping height is given by the equation: $\log h = 0.992 + 0.027$ cm. The relation between the W values and the temperature impact can also be formulated mathematically. The equation is: $\log T = 1.6 + 0.046\ W°C$. The breaking strength of the glasses therefore can be calculated by means of the Winkelmann formula as a function of the composition. This formula is valid only with de-stressed glasses. In order to test the usefulness of the above equations, *K* calculated the values of glasses, and compared them with the values found. As Table IV shows, the agreement is rather good. The equations for the dropping height and the thermal impact can be used in practice, and can serve as important aids in the production of the glasses.

TABLE III

No.	*S*
13	153
14	175
15	174
16	188
17	226
18	238
19	422

TABLE IV

	Thermal Impact			Dropping Height	
Glass	Calculated	Found	Glass	Calculated	Found
1	58	62	13	18	13
2	63	63	14	19	25
3	74	87	16	20	19
4	78	89	17	24	25
5	84	88	18	26	25
6	88	99	19	59	59
8	97	91			
9	111	104			
10	119	104			
11	145	148			
12	147	148			

E.J.V.

Design of plate glass polishing machines. III. F. W. PRESTON. *Glass Ind.*, **9** [4], 81–84 (1928).—Continuous polishing devices are discussed, using diagrams representing polishers in use in various commercial plants to explain the advantages and disadvantages of each type. The rotary type of glass-polishing machines are considered as contrasted with the old-fashioned "square polishers" and the modern continuous types. For preceding abstracts see *Ceram. Abs.*, **7** [5], 285 (1928). E.J.V.

Glass industry of Lancashire. L. MILNER BUTTERWORTH. *Pottery Gaz.*, **53** [609], 458–63 (1928).—An informative article dealing with the development of glass manufacture from the time of the ancients down to the present day and generation, and the development of the glass industry in the county of Lancashire, probably the greatest glass-producing county in England. The following topics are discussed: (1) early history of glassmaking; (2) beginnings of the English glass trade; (3) prohibition of wood as a fuel; (4) first record of Lancashire glass trade; (5) the manufacture of plate glass; (6) sheet and window glass; (7) early continental influences; (8) Irish glass works; (9) unsplinterable glass; (10) the Lancashire bottle trade; (11) recent developments and progress; (12) mass production; and (13) the electric bulb trade. A tribute is paid to W. E. S. Turner for his research work in glass. E.J.V.

A personality in the glass industry. ANON. *Pottery Gaz.*, **53** [609], 468–69 (1928).—A biographical sketch of Joseph Silvers Williams-Thomas, who has been associated with the firm of Stevens & Williams (his father's business) since 1864. He has devoted

himself to the improvement of the quality of the productions of the firm since then, particularly in the development of the higher class of English table glass services.

E.J.V.

Viscosity and allotropy of glass. LE CHATELIER. *Pottery Gaz.*, **53** [610], 643 (1928); reprinted from *Ann. de Phys.* and *La Ceramique.*—On interpreting the results of the measures effected by various authors as to the viscosity of glass, it was found that these results could be represented by a simple algebraic function. The double logarithm of the coefficient of viscosity varies in proportion to the temperature. According to an application of the graphics thus obtained, Le C. concludes that there is an allotropic transformation of the glass at a temperature corresponding to the variations already pointed out by numerous authors in the coefficient of expansion and in the specific heat.

E.J.V.

Elementary test for the disaggregation of glass. F. SPATE. *Pottery Gaz.*, **53** [610], 648 viii (1928); reprinted from *La Ceramique.*—It is proposed, as a critical test of glass from the point of view of the influence of atmospheric agents, to subject the article in question at a certain temperature to the action of an atmosphere of carbonic acid saturated with moisture, and at an ordinary temperature. The method of operation and the results obtained by this method for a series of different kinds of glass are given. E.J.V.

Absorption spectra of borax glass colored with copper. P. LASAREFF AND V. LAZAREY. *Pottery Gaz.*, **53** [610], 648 viii (1928); reprinted from *La Ceramique.*—The absorption of these glasses when steeped and annealed is the same. The spectrum of the glass covered with salts of copper, however, is different from that of solutions of copper-iron salts. It may be concluded that the coloration of borax glasses does not depend upon copper tones, but that it is produced by the complex compounds of the atoms of copper and of the molecules of borax. E.J.V.

Glass manufacture in Russia. ANON. *Chem. Trade Jour. and Chem. Engr.*, **82** [2122], 57 (1928).—Owing to shortage in supplies of soda ash, experiments were undertaken at the Leningrad Ceramic Institute to determine the possibility of making glass without manufactured alkalis. It was shown that nepheline, (a complex soda potash-alumina silica mineral) which occurs abundantly around Murman and in the Urals could be used for window and bottle glass. It is stated that raw material costs are cut 40%. L.P.C.

Automatic production of bulbs and tubing. ANON. *Glass*, **3** [13], 540–48 (1926).—This is a complete description of the British Thomson-Houston Co., Ltd., plant at Chesterfield. Both bulbs and tubing are made. The batches (lead glass for tubing and soda-lime for bulbs) are mixed in separate Smith type batch mixers of 5 tons capacity. Producer gas is supplied by Morgan gas machines completely equipped with steam pressure gages, thermometer for steam, thermometers and pressure gage for the blast, thermocouple in the gas outlet of the producer, and a CO_2 recorder. The metal level in the tank must be kept practically constant. The device which controls this is a refractory block that floats in the metal at the working end. Resting on this float is one end of a pivoted lever; the pivot and other end are outside the tank. The two arms of the lever are of equal length so that any downward movement of the float causes a corresponding upward movement of the external arm. On the end of the latter a lighted electric bulb is fastened. A lens is fixed in front of the lamp which throws an image of part of the filament onto a wall some distance away. The lens and distance are so arranged that the movement of the filament is magnified 100 times. This image is visible to both the man at the dog-house and the machine operator. The latter thus keeps a close check on the former. Westlake machines carrying 24 molds are used. After forming, the caps are removed by a "burning-off machine." The leer is 22 ft.

long and 13 ft. wide inside. A Hilger strain-viewer and a device for showing up cords or striae are used. For sizes which are required in small quantities two shops of hand workers are employed. The Danner machine is used for drawing tubing. The tubes are cut into equal lengths and automatically classified according to outside diameter and wall thickness. The output is about 10,000 lbs. per 24 hours. The special refractory shapes required are made at the plant. A.J.M.

Compressed air in glass manufacture. R. WILSON. *Glass*, **3** [13], 549 (1926).—W. discusses compressed air piping, loss due to leakage, pipe joints, screwed joint, flanged joint, patent joint, draining of pipes, expansion and contraction, bends and elbows, valves and pipe fittings, locating leakages, and air-inlet pipes. A.J.M.

Use of chromium for glass molds. ANON. *Glass*, **4** [1], 33 (1927).—The metallurgist has assisted the manufacture of glass by developing alloys which meet the following requirements: (1) capability of withstanding temperatures of 1000°C or above without serious loss of strength, and (2) immunity from oxidation at these temperatures. Glass molds may be protected by surface coatings of which nickel or chromium or both are essential constituents. The properties of chromium which make it important are (1) resistance to corrosion, (2) resistance to oxidation, (3) extreme hardness. The benefits to be derived from the use of such a coating are that it (1) obviates necessity for frequent cleaning, (2) saves labor and expense by less frequent cleaning, (3) increases life of mold. A.J.M

Joining metal to glass. G. W. C. KAYE. *Glass*, **3** [11], 455 (1926).—The prime requirement for metal-glass joints is that the coefficients of expansion be in close agreement over the temperature range used, or, that by proper design the stress shall not exceed the strength of the metal to glass union. For many years platinum was used exclusively but the increased price has caused the adoption of substitutes. By careful manipulation it is possible to seal a fine copper wire directly into glass. The following procedure is advised. Heat the copper in an oxidizing flame until coated with oxide. Dip it into a saturated borax solution and reheat. Repeat this process until a thin film of salt spreads over the metal and forms copper borate. Under these conditions glass will adhere to the copper when the two are heated in a flame. At the present time copper has been replaced by alloys with expansion coefficients nearly equal to that of the glass. The following alloys are used: (1) nickel-iron (about 50% nickel) for soda or lead glass, (2) 40% nickel coated with 20% copper for electric lamps and radio tubes, (3) 75% iron, 25% chromium, expansion 10×10^{-6} per degree C. The General Electric Co. has developed a method for joining glass to vitreous silica. The procedure is to join the soft lead glass to a hard glass through several special glasses in diminishing order of expansion coefficients, the hard glass being then joined to Pyrex. The free end of the Pyrex is heated in a flame until it has lost sufficient boric oxide to enable it to weld to the silica. Each glass is completely fused so that it largely loses its identity. A.J.M.

The production of pressed ware. ANON. *Glass*, **3** [11], 456 (1926).—The following table shows the production of pressed ware that is being obtained in American factories.

Article	Production per minute	Article	Production per minute
Light table tumblers	28	Butter boxes	14
Heavy " "	23	" covers	19
3-pint water pitcher	10	5-inch compote	15
2-handled sugar	14	Sundae	22
Creams, pressed handle	15	6-inch plates	15
Sherbet, flat foot	19	" " vase	16
Ash trays	20	2-handled pickels	25
4-inch Colonial nappy	26	Orange reamer	13

Article	Production per minute	Article	Production per minute
4-inch plain or star bottom	32	Flat foot wines	18
4- " mixing bowl	24	Jugs, 57 ozs. capacity	9
6- " " "	18	" 34 ozs. capacity	11
9- " " "	10	" 21 ozs. capacity	13
Sugar covers	25	Large creams	15
5-inch handled nappy	18	Small "	19
5- " footed jelly	15	5-inch nappy	22

A.J.M.

Regenerators and dampers in the glass industry. ANON. *Glass*, **3** [11], 457 (1926).—It is important to have pyrometers for indicating the temperatures in the regenerators. To enable close adjustment, 2 dampers should be provided, one in the flue from the gas chambers to the chimney and the other in the air flue to the chimney. This arrangement gives the furnace man complete control over the distribution of the waste gases between the 2 chambers. If this is not done, the air and gas regenerators on each side may not receive the proper amounts of hot gases and there will be no method of control. The 2-damper arrangement obviates this difficulty. Careful work should be done to determine the shortest interval at which reversals can be made economically. This time-table should be strictly adhered to except on rare occasions when it is advisable to depart from schedule. Drawings are given for mica windows which enable the operator to look into the regenerators. These are designed to prevent the entrance of cold air.

A.J.M.

A "taking in" device for glassware. ANON. *Glass*, **3** [11], 459 (1926).—A photograph shows the method for taking the ware from the machines to the leers that is employed by J. A. Jobling and Co., Ltd., British and Colonial manufacturers of Pyrex glass. The process requires an overhead runway which is used to transport the trays which carry the ware.

A.J.M.

Gasified fuel in the manufacture of glass. *Glass*, **3** [11], 465 (1926).—The use of pulverized coal as fuel has suffered as a result of being applied to installations for which it is not suited. The main objection to its use in glass furnaces is the ash content of the coal. If the fuel were projected into a tank furnace the fused ash would contaminate the metal. The process is used for pot furnaces. A method for using pulverized coal has been devised for tank furnaces. The pulverized fuel is burned in a separate chamber with insufficient air for complete combustion. The resulting gases pass into the furnace proper where combustion is completed. The ash difficulty is obviated in this manner.

A.J.M.

Oil burners for use in the glass industry. W. A. HUBBARD. *Glass*, **3** [11], 467–69 (1926).—Two factors are important in the use of oil fuel, (1) selection of the proper type of burner, (2) correct application of the burner selected. The low pressure air operated oil burner has the advantage of lower initial running and maintenance costs. In tank furnaces the burners are either set at each side and firing across the tank or are placed at the charging end. Care should be taken to see that there are no localized heating effects which may cause uneven expansion and contraction. Side-firing applications are usually employed where a quick conversion to oil burning is desired. In such cases the existing regenerators are used with fuel oil. Where a furnace is being permanently converted to oil, firing at the charging end is recommended. Regenerators are not used but the secondary air is preheated by means of recuperators situated above the crown. With oil firing, two to four tons of finished glass per ton of oil burned may be produced. Much depends on the design of the furnace. The conversion of pot furnaces to oil burning is a more difficult matter. The usual method is to insert the burners so that the flames are projected tangentially around the furnace above the pots, or one pot may be removed and the flame projected into the furnace. Two burners are generally used.

The most satisfactory method is to fire the furnaces centrally below the siege, the oil flames entering in the same manner as when gas fired. The application of oil burning to annealing cannot be standardized because of the large number of leer designs. The flame should be of low velocity and there must be no intense local heating. A single combustion chamber is found to give good results. When one class of ware is always annealed a thermostatic control will give constant temperature. Some types of glory holes use more than twice the necessary amount of oil and are very wasteful. A.J.M.

Compressed air for glass blowing. R. WILSON. *Glass*, **3** [11], 473–75 (1926).—W. gives practical information, sample calculations, etc. Position and construction of air receivers are discussed. A.J.M.

Compressed air in glass manufacture. R. WILSON. *Glass*, **3** [12], 499–501 (1926).—W. gives the requirements for compressed air piping, discusses frictional losses in transmission, shows calculations for pipe diameters, loss of pressure, and number of branch pipes. A.J.M.

Glass breakage. J. SCOTT. *Glass*, **4** [1], 31–33 (1927).—A small clean-cut round hole pierced the glass as if it had been drilled. Around the perforation was a scalloping or mass of conchoidal fracturing. The action evidently had been sudden and sharp. There were two possible causes. A stone may have been thrown deliberately or a small stone may have been cast up from the roadway by the wheels of a passing bus. The location of the hole was such that the latter cause seemed most probable. The real fracturing occurred on the inside, that is, the chipping happened on the surface opposite to that which received the full force of the impact. A.J.M.

The elements of thermochemistry and applications to glass. H. V. E. RENN. *Glass*, **4** [1], 4–7 (1927).—R. gives in detail the principles of combustion, heating or calorific value, calculations of calorific value, heat required to melt glass batches, etc. A.J.M.

An oil-burning installation in the glass industry. ANON. *Glass*, **3** [12], 518 (1926).—The requirements for a suitable oil-burning installation are: (1) absolute atomization of the oil by the burner itself before combustion begins to take place, using the minimum energy, in the form of compressed air; (2) complete combustion of the resulting oil mist, by means of a clean flame, nowhere in contact with the brick work and making no smoke; (3) a design so arranged that (*a*) a burner can be constructed to "fit" any size, shape, or type of furnace, and (*b*) a flame suitable for each particular job can be produced; (4) ease of adjustment, flexibility, and absolute reliability; (5) the maintenance of the furnace at an even temperature of at least 1200°C. With the type of burner described 1 cu. ft. of air per minute at 25 lbs. pressure is required per gallon of oil per hour. Photographs show the great flexibility of the burner as well as the good agreement with the requirements mentioned above. A sketch of the burner completes the article. A.J.M.

Decomposition of glass; some minute formations. J. SCOTT. *Glass*, **3** [12], 507 (1926).—Damp air is capable of affecting even special chemical glasses. The action is due to the formation of new compounds of potash and soda which have increased solubility. In the case of acid solutions the potash is more susceptible to action. Flint glass with a moderate or high lead content seems to be most immune to this defect. In contact with acid solutions silicates of potash and soda may be formed and these are easily dissolved. Glass vessels in which water or chemical fluids are boiled may be affected physically by the vibrations due to ebullition. S. believes that electrical and magnetic changes occur. Rain water may be harmful because of the particles picked up in its fall through the atmosphere. Grit and dust particles are forced into the cracks made by chemical agents and tend to cause small fractures. Invisible fissures may become scalelike and the detachment of the latter can be readily seen as unsightly

patches. Mirrors are often spoiled in this way. Glass that can be readily fused is extremely liable to decomposition. Water is absorbed by such glasses and it dissolves the soluble constituents. Glasses low in lime are subject to the same action. When the glass is heated it breaks because of the expansion of steam in the glass. This occurs with lamp chimneys. If these are left for long periods of time in humid places they are liable to shatter when used. In some cases a wrinkled surface skin is found on the glass and this may be peeled off if decomposition has penetrated deeply. Water does not enter into true chemical combination but causes the formation of hydrated products. It is practically impossible to determine the directions of decomposition marks. Many of the lines or scratches seem to have brush or comblike tufts along their courses. These are apparently arcs of circles which pass downward into the glass. Such defects occur mainly in glasses which are subjected to alternate heating and wetting. All visible defects in glasses have had microscopic origins. A.J.M.

Melting glass by electricity. ANON. *Glass*, **4** [4], 140–43 (1927).—This method may prove very useful in countries such as Norway where there are extensive hydro-electric developments. The furnace here described is located at Moss, Norway, and was constructed by Bjorn Raeders. In the usual gas-fired furnace the holding capacity is from 8 to 10 times the normal daily production. About 8900–15,000 B.t.u. are required per pound of glass melted. In the electric furnace the rate of heating is accelerated to a figure impossible with any system of heating by flames, with the result that the dead weight capacity of the furnace can be reduced to 1 to 1.5 times the daily output instead of 8 to 10 times. There are two ways in which electricity may be applied to glass melting: (1) by use of the electric arc and (2) by means of resistance. Some attempts have been made to combine electrical and coal- or gas-fired furnaces, the melting being done by electricity and the fining and working temperature maintenance requiring coal or gas. Bronns used the electric arc in such a furnace. The electricity consumption was high (1.1 kw. hrs. per lb. of glass) and the glass was dark colored and unsuitable for general use. Birkeland-Eide proposed systems using the electric arc but these were never used. The disadvantages inherent to the use of the electric arc are (1) intense local heat and high temperature cause loss of alkali; (2) local heating has a serious effect on the surrounding brickwork; (3) there is considerable expense and trouble in the renewal of carbon electrodes for the arc; (4) the glass is discolored by carbon particles. These difficulties may be obviated by the use of indirect resistance heating but this in turn has the following disadvantages: (1) loss of efficiency due to transmitting the heat through clay pots; (2) the pot itself is a source of trouble; (3) difficulty of obtaining durable and satisfactory resistance material; (4) because of intensely high temperature and local heating the source of heat must be placed some distance from the walls and the distance factor means lower efficiency. Rennerfelt suggested the use of covered electric arcs outside the glass pots but the efficiency would be low and electrode renewal expensive and troublesome. From the standpoint of thermal efficiency the souce of heat should be inside the pot. The Raeders furnace is of this type. Molten glass is a conductor of electricity and the glass itself can be used as the electrical resistance or heating element. The advantages are (1) the heating occurs in every part of the mass of material and throughout the whole section of the tank; (2) the amount of heat transmitted is no longer dependent upon the area of surface exposed to heat radiation and hence it is possible to obtain the most favorable shape and section from the viewpoint of heat conservation; (3) the rate of melting may be accelerated and the dead weight capacity reduced. This results in lower initial cost and reduction of radiation and other heat losses. The first commercial furnace was built in 1925 and produced 330,000 saleable bottles in 3 months. It melted 9 to 10 tons of glass per day. To prevent contamination of the glass by the electrodes the alkalis of the batch are kept from

coming in contact with them. Such contamination is prevented in two ways: (1) the half-molten batch is lighter than molten glass and floats; the electrodes are so placed that they are wholly submerged and the alkali does not come in contact with them; (2) the contact surfaces are kept cool either directly or by using large section electrodes and large contact area by fluting the electrodes. The electrodes are built into the walls of the furnace and are placed at the sides; 3-phase current is employed. The batch enters the rear of the furnace and a baffle wall retains it until it is melted. It then passes into the refining section and then into the working end. The heat radiated by the crown is used to preheat the batch which passes over it and is fed into the rear of the furnace by means of a screw conveyer. The alkali and cullet are not preheated because such action would cause caking. The furnace requires practically no regulation and one man easily controls 3 furnaces. One kw. hr. melts one kg. of glass. The fuel saving relative to a coal-fired furnace is 70%. The initial cost is much lower since no gas producers, boilers, coal storage, flues, regenerators, etc., are required. The space occupied by the furnace is also less. The electrical equipment is expensive but the cost of installation is only $^1/_4$ to $^1/_2$ that of a gas-fired furnace of equal capacity. The small glass capacity allows a quicker change from one color of glass to another. The operating conditions are much cleaner and there is no loss of alkali. A.J.M.

Viscosity of glass. ANON. *Glass*, **4** [4], 151 (1927).—Part of the National Physical Laboratory Report for 1926 is reviewed. Viscosity appears to be a definite function of the temperature for variations between 1200 and 1500°C provided that the glass is initially homogeneous. Cooling the glass to room temperature and reheating does not change this function if the action is sufficiently rapid within a critical temperature range which lies below 1200°C where the viscosity measurements give evidence that the glass exists in at least two states. Hence, these measurements give the first quantitative confirmation of a variation in the constitution of glass at high temperatures as a result of thermal treatment. A.J.M.

Glass fragments in foodstuffs. ANON. *Glass*, **4** [4], 166–67 (1927).—The results of investigations show that the occurrence of glass particles in food is relatively uncommon due to the fact that most manufacturers use good glassware. When present, the glass is usually in powder or microscopic size and there is little, if any, evidence to show that in this form it is capable of exerting any injurious effect when swallowed with the food. Automatic processes are said to produce containers which are usually freer from defects than those made by hand or by semi-automatic methods. The bursting of bubbles and seeds may contribute glass to foodstuffs if cheap containers of inferior quality are used. Glass may enter during the process of filling and great care must be exercised to prevent this. Extraneous sources of glass must be considered. One source of danger is the adhesion of factory dust and even road dust picked up by fruits in transit. A.J.M.

Test methods of the German pharmacopœia for medicinal glassware. WERNER MYLIUS. *Keram. Rund.*, **36**, 22–23 (1928). H.I.

The evaluation of special eye-protective glasses. L. BLOCH. *Gas u. Wasserfach*, **70**, 1229–32 (1927).—Methods are given for testing eye-protective glasses as to their transmission in the visible, infra-red, and ultra-violet ranges. In the latter range a standard quartz lamp is used and the transmission is estimated from the degree of fluorescence excited on standard test paper. Results obtained in that way check well with spectrographic results. (*C. A.*)

"Kinon," a new glass. E. O. RASSER. *Kunststoffe*, **17**, 246–47 (1927).—The properties of "Kinon", a new non-shatterable glass, are described. It is prepared by inserting a sheet of celluloid between 2 sheets of plate glass. (*C. A.*)

PATENTS

Apparatus for severing glass sheets. TRAVIS AND ALFRED C. OAKES. U. S. 1,661,846, March 6, 1928. An apparatus for separating sections from a continuously formed advancing sheet of glass, comprising electric heating means extending transversely of the sheet, means for clamping the heating means against the sheet so that it moves along with the sheet during the heating operation, and means actuated by the movement of the sheet for causing the clamping means to be actuated.

Glass-forming machine. ALBERT N. CRAMER. U. S. 1,662,848, March 20, 1928. In a glass-forming machine, the combination of a mold open at its upper end to receive a charge of glass, a guide normally arranged to direct the charge into the mold, a mold closing head adjacent one side of the mold, means to move the head into and out of position to close the upper end of the mold, and connections between the head and guide actuated by a movement of the head for moving the guide relatively to the head in a direction transverse to that of the head, into position to prevent interference with movement of the head.

Glass-forming apparatus. JOHN E. MCLAUGHLIN. U. S. 1,662,861, March 20, 1928. The combination of a mold carrier shoe, a hinge pin plate spaced above the shoe, a hinge pin plate holder interposed between the plate and shoe, means separably connecting the shoe, holder, and plate, and means interconnecting the holder and plate including devices to effect individual or simultaneous adjustment of the holder and plate with respect to the shoe.

Manufacture of glass tubing and cane. KARL E. PEILER. U. S. 1,663,093, March 20, 1928. Apparatus for continuously drawing glass in tubular form, comprising a conical receiver inclined downwardly toward its smaller end and having a flange at its larger upper end, a gear ring and an annularly grooved bearing member clamped to opposite sides of the flange, rollers engaging the groove of the bearing member for rotatably supporting the receiver, means for driving the gear ring, a stationary closure member adjacent to the gear ring, means for introducing compressed air into the receiver through the closure member, means for preventing escape of air between the gear ring and closure member, means for introducing a stream of molten glass into the receiver, comprising a feed tube extending through an opening in the closure member and having an external flange for supporting the feed tube and for preventing escape of air from the receiver around the feed tube, and means for supplying a regulated quantity of molten glass to the feed tube.

Process of checking molds designed for the molding of glassware. OLIVER C. K. HUTCHINSON. U. S. 1,663,306, March 20, 1928. The process of checking a mold designed for the molding of a definite article of a predetermined shape or volume and material, comprising, filling the mold cavity with another moldable material to form therein a test piece conforming thereto, and measuring the displacement of the test piece in order to determine the accuracy of the mold.

Flowing and drawing continuous sheet glass. ENOCH T. FERNGREN. U. S. 1,663,628, March 27, 1928. An apparatus for continuously producing sheet glass, comprising a receptacle for the molten glass having an overflow lip at one end thereof, the overflow lip comprising a separate member mounted parallel to and slightly spaced from the overflow edge of the receptacle, so that the flowing glass will pass both over and under this member and unite to form the sheet source at the outer edge of the member, the member being formed with horizontal glass retarding ledges to impede the free flow of the glass.

Glass furnace. THOMAS B. HART. U. S. 1,663,839, March 27, 1928. In a glass furnace, a melting furnace, a drawing tank in communication therewith divided into a series of alternating reheating chambers and drawing wells and a separate and distinct

heating means for each well constructed to supply heat thereto proportionate to the depreciation of the glass flowing through the tank, to retain the glass in a uniform texture throughout the various wells in the process of drawing.

Glass feeding mechanism. THEODORE C. STEIMER. U. S. 1,663,925, March 27, 1928. A measuring and interrupting device, comprising a receptacle having an outlet, a stopper adapted to constrict the outlet, a flame under the outlet, and mechanism to automatically operate the stopper at predetermined times to a regulable degree.

Machine for finishing glass tubes, bars, vials, bottles, etc. LEON JEAN BROCHE. U. S. 1,664,154, March 27, 1928. In a machine of the character described, a conveyer including two conveyer screws arranged in parallel relation and common plane, and each mounted for rotation in proper direction to move laterally an article bridging the screws and extending into the threads thereof, each screw being also provided at a like point in its length with an offset in its thread extending partially around its body in a direction perpendicular to the axis of such screw, and serving to hold the article treated temporarily against lateral movement yet permit continuing rotation of the screws.

Process and apparatus for grinding and polishing glass. FRANK EDWIN SLOCOMBE. U. S. 1,665,117, April 3, 1928. (1) Apparatus for the abrasive treatment of glass, comprising apparatus for supplying abrasive media, rotating tables on which the glass is laid, a truck carrying each table moving past the apparatus supplying the abrasive media, means on each truck adapted to rotate the table, rails on which the trucks travel, abrading runners adapted to operate on the glass, and means for traveling together the trucks and the runners, during the operation of the runners on the glass. (2) Apparatus for grinding and polishing plates of glass of the type in which the glass is laid on tables which are rotated under grinding and polishing runners to effect the grinding and polishing, comprising a truck carrying each table, means on each truck adapted to rotate the table, rails forming a closed circuit round which the trucks are adapted to travel, means operative to move the trucks along the rails, a grinding runner frame and a polishing runner frame adapted to travel with each table during the operative course of each runner frame, a runway for the grinding runner frame and a runway for the polishing runner frame, the runways forming each a closed circuit of which a portion is adapted to support the runner frames while traveling with the tables while the remainder is a return circuit, means for attaching the grinding and polishing runner frames to each truck at the beginning of their operative courses and detaching them at the end thereof, means mounted on the runner frames adapted to raise and lower the runners, and stationary cam surfaces coöperating with means to effect such raising and lowering.

Glass feeder. VICTOR E. HOFMANN AND LEONARD D. SOUBIER. U. S. 1,665,362, April 10, 1928. In combination, containing means for molten glass having downwardly directed outlets, regulating plugs projecting downward into the glass over the outlets, and means actuated by a pendulum regulator operating within the glass between the openings for periodically reciprocating the plugs, including connections between the plugs, whereby as each plug is moved downward, the other plug is moved upward.

Manufacture of strengthened glass. PERCY HERBERT HEAD. U. S. 1,665,413, April 10, 1928. Laminated glass, comprising a plurality of sheets of glass having interposed between adjacent sheets a celluloid strengthening sheet, a cementing material for uniting the celluloid sheet to the glass sheets, and a combined solvent and cromatic stabilizing mixture comprising industrial spirit, amyl acetate, and tetrachlorethane.

Manufacture of raw plate glass on multiroller glass rolling machines. LAMPERT VON REIS. U. S. 1,665,427, April 10, 1928. (1) A multiroller glass rolling machine for manufacturing raw plate glass, comprising a tiltable receiver for the molten glass mass to be rolled out, a tiltable rolling mechanism, and adjustable chutes and guide rollers for guiding the rolled glass plates to conveying means. (2) The combination in a glass plate roll machine of a receiver for molten glass, a pair of sheet forming rolls with a

pass between them, adapted to receive glass from the receiver, and to make it into sheet form, the receiver and the forming rolls being independently movable about a common axis.

Glass and its manufacture. ELBERT E. FISHER. U. S. 1,665,693, April 10, 1928. A batch for glass production comprising a substantial proportion of barium sulphate as a primary ingredient and producing, when melted, a glass which is capable of being effectively decolorized by selenium and which solidifies to a clear transparent product.

Glass and its manufacture. ELBERT E. FISHER. U. S. 1,665,694, April 10, 1928. A glass-forming batch containing barium sulphide as a primary ingredient.

Smoothing and polishing glass, etc. PAUL JOSEPH MAXIMILIEN ESCOLE. U. S. 1,665,776, April 10, 1928. Smoothing and polishing apparatus, comprising a battery of stationary tables of great length, whereon the material undergoing treatment is adapted to be secured, fixed side by side in spaced, parallel relation; parallel tracks extending along the opposite ends of the tables at right angles to the latter; carriages adapted to travel along the tracks; and abrading devices adapted to travel longitudinally over the tables for polishing the material secured thereon from end to end thereof, and adapted to be moved from the end of one table to that of the next by means of the carriages.

Glass manufacture. SOC. ANON. DES PAVILLONS. Brit. 283,870, March 14, 1928. A hand-operated machine of the kind in which the charges of glass are settled in the parison mold by compressed air admitted above the glass through a cover plate which closes the open ends of the molds. According to the invention, the sealing-face of the cover plate is perforated with holes through which the compressed air is admitted to the mold, but which are too small to allow the glass to pass through them when the parison is blown up against the cover.

Glass manufacture. SOC. ANON. DES MANUFACTURES DES GLACES ET PRODUITS CHIMIQUES DE ST.-GOBAIN, CHAUNY, ET CIREY. Brit. 284,648, March 28, 1928. A glass to be used for X-ray screens contains lead oxide and barium oxide. The proportions of the two oxides are determined by the formula

$$B \times 1 \cdot 005^{(P+250)} = 110$$

in which B indicates the content of barium oxide and P the content of lead oxide. A suitable glass contains 45% lead oxide and 17% baryta.

Manufacture of bottles and medical capsules. F. MEYER. Brit. 284,888, March 28, 1928. Relates to a glass vessel such as a food container, vial, ampoule, etc., which is provided with a cracking-line to enable it to be opened by breaking off the neck or other part. According to the invention, the glass, while hot during manufacture, is chilled by contact with a cold body. As a result, the finished vessel is strained along the line of chilling and a slight injury to the glass at this point causes it to crack off cleanly along the line.

Heavy Clay Products

Brick machine, bucket elevator, and hammer mill power determinations. D. P. OGDEN. *Jour. Amer. Ceram. Soc.*, **11** [5], 310–13 (1928).—Power measurements on brick machinery are determined and compared.

Natural protective crust on stone. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, pp. 31–32 (1928).—A theory held by many individuals, that a protective coating is formed when natural stone is exposed to weathering, has recently been disproved by tests at the Bureau. Two sets of specimens, one from the surface and the other 4 in. below the surface, were prepared from samples of stone aged in window sills 30–40 years. These were tested for permeability, absorption, and abrasive hardness. In all tests

the results indicate that stone near the weathered face is more absorptive, more permeable to water, and softer than the material 4 in. below this surface. Permeability of the surface specimen of the 40 year old stone was about twice that of specimens cut from the interior. The hardness tests indicate that the weathered surface is abraded about 50% faster than the unweathered stone. R.A.H.

Lamination and core cracking in wire cut brick. J. E. KIRCHNER. *Brit. Clayworker*, **36** [431], 358–59 (1928).—K. points out the importance of a knowledge of the laws governing the friction effect produced by moving clay. Two features of this action are taken into account, (1) the friction of the clay when its particles are in internal movement, and (2) friction produced when the clay slides over the interior surfaces of the barrel, over the shaft with its knives and expelling worm, and over the lubricated faces of the die. The larger the particles of sand or grog, the greater the friction, and a sandy clay offers more resistance to propulsion than a strong smooth material of fine grain. A second source of resistance is the cohesion of the clay itself which varies with the nature of the clay and its moisture. The table shows the variations in the coefficient of friction of a clay in different states on the surface of various materials.

	Dry	Wet	Lubricated
Clay on wood	0.5	0.35	0.25
Clay on cast iron	0.28	0.20	0.14
Clay on brass	0.2	0.14	0.1
Clay on tinned iron	0.15	0.1	0.08
Clay on clay	0.6	0.42	0.29

The resistance of friction to be overcome in passing a clay column through a die is of two kinds: (1) the resistance of friction due to adhesion, when clay passes over a wood or metal surface, (2) the resistance due to the attractive force of the clay molecules or cohesion of the material. The correct length of die can be calculated if the coefficient of friction between the clay and lubricated die surface is known. The twisting movement of the clay caused by the propelling worm results in an S-shaped line in the brick. This effect is not as undesirable as the polished surfaces of the clay, caused by the blades of the propelling worm, and which will never unite. Unless a die is designed in such a way as to equalize the speed of travel of the interior and exterior surfaces of the clay column various effects detrimental to the quality of the brick are produced. Precautions to be observed are: (1) lubrication of the surfaces of mouthpiece and die over which the clay is forced; (2) the speed of travel of the clay on all surfaces of the column equalized by forming two orifices, one on each side of center line instead of a single opening; (3) the central interior portion of the clay may be retarded by fixing an obstacle in the interior of the contracted portion of the pugmill behind the die; (4) the expelling worm on the shaft of the pugmill should always terminate level with the end of the parallel part of the clay barrel and an ample length of mouthpiece provided. R.A.H.

Bricks from washed gravel. WILLIAM L. HARE. *Brit. Clayworker*, **36** [431], 360–62 (1928).—Description of a modern plant manufacturing about 80,000 bricks from by-product clay obtained in gravel mining. R.A.H.

Testing paving brick. J. A. VAN DER KLOES. *Brit. Clayworker*, **36** [431], 364–66 (1928).—A discussion of the shortcomings of the present methods of testing paving brick and the substitution of the ball test such as devised by J. A. Brinell for steel, is recommended. The test consists in laying the brick in a suitable box of sand and filling the interstices with sand. The middle brick (the victim) is subjected at its center to the pressure of a steel ball 19 mm. or $^3/_4$ in. in diameter until failure occurs. R.A.H.

Preparing shale for semidry brick manufacture. ANON. *Brit. Clayworker*, **36**, [431], 367 (1928).—The method which is still in the experimental stage requires the following train of machinery: crusher to break down the lumps to a size suited for

grinding; high speed rolls designed for fine grinding, the rolls being separately driven at slightly different speeds; a shredder designed to convert the ground shale into small chips of fairly uniform size. From here it is carried to a newly designed machine which is intended to take the place of the dry pan and reduce the shale to a state of division suitable for the press. The mill has three pans of the same design each placed directly above the other with perforated bottoms. Material is fed into the upper pan and passed to and fro on the grids by means of scrapers. Hot air is passed up through the grids to prevent sticking of the shale. When the material passes through the lower pan it is fine enough for use. A great saving in power is realized by this arrangement. R.A.H.

Industrial research and the brick industry. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, p. 33 (1928).—Although brick making is an ancient industry very little is known of the underlying scientific principles which control the quality of the product. Progress is being made, however, in the solution of some of the important problems through the hearty coöperation of the Common Brick Manufacturers Assn. and the Bureau of Standards. Kiln processes are being studied, the strength, fire resistance, and sound transmission of brick walls have been determined, and the efficiency of brick-making machines is being measured. R.A.H.

New patented hollow building tile developed. ANON. *Brick Clay Rec.*, **72** [6], 413 (1928).—Whitacre-Greer Fireproofing Co. has developed a new type of hollow building tile called "Wedge Block" which provides a nailing base for attaching strip of any kind. On each side of the clay tile block a greatly enlarged key groove is provided into which wooden wedges are placed and driven tightly together. It is then possible to nail to these wedges all wood or metal trim, base board, picture molding, and even blackboards for schools. The nail clinches when it strikes the tile, thereby forming a strong base for receiving the finish. E.J.V.

Strength and physical properties of brick masonry. L. B. LENT. *Brick Clay Rec.*, **72** [6], 414–20 (1928).—For the first time the common brick manufacturers are in possession of technical data on the performance of brick in walls which compare in authority and accuracy with those on any other masonry material. The article contains valuable data on brick wall strength, compressive strength for both solid and hollow walls, fire resistance, sound and moisture penetration, and other properties which mean so much to the builder. E.J.V.

Clay preparation as the foundation for a good tile. ERNEST W. KNAPP. *Brick Clay Rec.*, **72** [7], 476–79 (1928).—Different methods of winning the various kinds of clays used for manufacturing hollow tile are discussed. The methods of "doctoring" the raw material used in some localities where the clays have an excessive shrinkage are taken up. It has been found that a mining method by which the material is dug out of the solid will generally give the surest mix and retain the most of the original moisture. The first consideration is to find the method of grinding which tends to give the raw material the best possible form for the greatest tensile strength possible to attain by the pugging operation. In the business of making hollow tile, pugging is of such importance that consideration should be given to it in mining and grinding and all operations leading up to the actual pugging should be carried on in such a manner as to assist as much as possible. Dry grinding and screening would only be resorted to where the shale to be used is so very hard that it is compulsory to reduce it with crushers before dry panning. Various methods of grinding are discussed taking up the advantages and disadvantages of the various types of grinding mechanisms. The best equipment for the purpose must be installed regardless of price. E.J.V.

Reclaiming markets for brick. CHARLES A. BOWEN. *Brick Clay Rec.*, **72** [7], 480–86 (1928).—B., general manager of the Detroit Brick Manufacturers and Dealers Assn.,

has done a great deal of constructive work for the brick industry by following up advertizing and promotional work with consistent sales effort thus opening new markets for brick and regaining many that have been lost for years. Several markets have been gained for common brick by advocating use of brick in basements, white paint on brick walls, brick for back-up material, colored mortar, skintled brickwork, brick in partitions, ideal wall construction, and new cleaner for brickwork. Valuable data on the transmission of sound through brick walls has been gained, and much good work has been done with the bricklayers' school in Detroit. E.J.V.

Western Haydite. ANON. *Brick Clay Rec.*, **72** [7], 486–87 (1928).—The process of manufacturing Western Haydite is to take the shale from the bank in the same way as for making brick and grind it down to a maximum size of one inch. After grinding, the shale is conveyed to rotary kilns of the same type used in Portland cement manufacture. The shale contains its natural moisture content. It travels continuously through the kilns, passing through various stages of heating until, at the discharge end it is subjected to a kiln temperature of about 2000°F, or 100–150° higher than is used in firing the various brick and clay tile made of the same clays. The passage of the shale through gradually increasing temperatures prepares it for the expansion process, which actually converts shale to Western Haydite, when it reaches the zone of highest temperature. Here the shale becomes viscous, incipient fusion has taken place, the carbon content has oxidized and formed gases, with the result that the shale has expanded into a lightweight, cellular structure. The expansion process is so complete that the finest particles, even down to 48-mesh in size, show an ideal cellular structure when magnified. The resultant product, Western Haydite, is a series of air cells, the partitions of which are thoroughly vitrified fused shale, impervious and of great structural strength. The product is discharged from the kilns in clinker form and is then taken to the preparation plant where it is ground, screened, and graded into all the standard commercial sizes used in concrete. Comparisons of weights of Haydite cement block used in walls with other commoner materials are made, showing it to be the lightest. It passes the strength requirements of all local and State building codes, stands up under the fire test, has favorable heat and sound insulating properties, is damp-proof and has slight absorption, and makes an ideal base for the application of plaster and stucco. E.J.V.

Research on heavy clay products. GEORGE K. BURGESS. *Brick Clay Rec.*, **72** [8], 550–52 (1928).—In studies above 110°C, water smoking offers no difficulty in itself but the time required to fire ware is controlled by the relative ease with which the wares can be dried and oxidized. In the study of the two-cell hollow tile column it was found that the single winged auger is more efficient than the double or triple-winged, both in output per unit of power and quality of ware. Longer collective spacers are required for hollow tile dies than for brick dies in order to overcome the column defects produced by an uneven pressure back of the cores. Heat transfer measurements on two 8-inch plastered brick wall panels, one plastered directly on the brick and the other plastered on metal lath over ¾-inch furring strips showed that the latter wall was about 38% better insulator than the former. E.J.V.

Correct auger design in hollow tile manufacturing. ERNEST W. KNAPP. *Brick Clay Rec.*, **72** [8], 554–57 (1928).—How correct auger design, which is so essential a process in efficient clay plant operation, was determined is thoroughly discussed. All the numerous experiments tried, the reasons why they failed, and finally the correct auger design are described in detail. E.J.V.

Power requirements on a clay products plant. CHAD L. ARCHIE. *Clay-Worker*, **89** [4], 295–97 (1928).—Performance of three small Diesel units used to furnish the power at the Corinth Brick Co. is discussed. A comparison of costs of this power and purchased central station power shows a saving in favor of the Diesel engine power. E.J.V.

Effects on color on face brick using high or low sulphur coal. ANTON VOGT. *Clay-Worker*, **89** [4], 302 (1928).—When using coal high in sulphur considerable difficulty is encountered in obtaining good red face brick from red firing clays, the sulphur gases causing the fired brick to be a dirty brown or gray in color. Sulphur gases from high sulphur coal also attack salt glazed ware, dulling the gloss though the substance of the glaze is still there. Remedies are suggested. E.J.V.

Clay veneering by the Poston process. WM. H. MOSELEY. *Clay-Worker*, **89** [4], 302–304 (1928).—A detailed description of the Poston process of veneering is given, enumerating all its special advantages. Results of tests made on veneered products produced by this process are described and an analysis of the operating costs is given. E.J.V.

Evolution in brickmaking and brickmaking machinery. VI. GEORGE M. FISKE. *Clay-Worker*, **89** [4], 306–307 (1928).—The second and third periods, or the developing and modern periods in the production of brickmaking machinery are discussed. Several illustrations tracing the development of equipment during the middle period are included. For previous articles see *Ceram. Abs.*, **7** [4], 233 (1928). E.J.V.

British to revise standard sizes of brick. ANON. *Contract Rec. and Eng. Rev.*, **42** [10], 260 (1928).—Science Committee of the Royal Institute of Science is discussing revision of standard brick sizes. The important thing is the number of bricks that can be laid, and some believe that thick bricks can be laid more economically than thin ones. The present standard was adopted 24 years ago. L.P.C.

Treatment of calcareous stones with sodium silicate. PAUL GAVELLE. *Chim. e Ind.*, **18**, 564–85; *Rock Prod.*, **31** [6], 101 (1928).—The mechanism of the silicification of calcareous building stones after treatment with sodium silicate is explained. The solution dries on the surface with the formation of a film of gel which slowly becomes irreversible, while crystals of hydrated sodium metasilicate form in the interior. The outer layers are slowly decomposed by the carbon dioxide of the air with the deposition of amorphous silica, the sodium carbonate simultaneously formed being washed away by rain. The solution which has penetrated into the pores of the stone is slowly decomposed by the impurities present, calcium carbonate itself being inert, and insoluble double silicates are thus formed in the pores, strengthening the resistance of the stone to further atmospheric denudation. F.P.H.

Heavy clay products plants of Ohio. Ohio Ceram. Ind. Assn., *Bull.*, No. 4 (1928).—The plants and their locations are listed. F.P.H.

Manufacture of dry-press brick by the dry-press process. C. E. BALES. Ohio Ceram. Ind. Assn., *Bull.*, No. 5 (1928).—When the first dry press was installed in a firebrick plant, it was thought that only plastic clays could be used, but after many years of experimenting, it has been found possible to use highly refractory, nonplastic flint clays without the addition of any bond clay. Even chrome and magnesite brick are being produced successfully by the dry-press method. One of the most important factors in the successful production of dry-press fire brick is the preparation of the clay. No definite rules can be set down for proper preparation, because clays vary so widely in their physical characteristics. It is generally agreed, however, that the items to watch are the grinding and sizing, the moisture content, and the thorough mixing of the clay particles before pressing. Several different methods are used in preparing the clay. In some plants the raw material is crushed in a dry pan and all the water added at this point. The clay is screened and stored in a damp condition. In other plants, the clay is crushed in a dry pan without the addition of water, and the screened material passed through a pug-mill mixer. Here the water is added and the damp clay conveyed to storage bins. Another very successful method coming into use with clays of low plasticity is as follows: The clay is crushed dry, screened, and stored in bins. A definite

quantity of clay is drawn from the bins, placed in a regular wet pan, where a definite amount of water is added, and the batch ground for a certain length of time. The damp clay is then removed from the pan, passed through a disintegrator and then conveyed to the mixer above the dry press. The poidometer with liquidometer attachment is also coming into use in connection with the preparation of dry-press clay and it is found to be quite satisfactory. The pyrometric cone equivalent of dry-pressed brick is slightly higher than of brick made by either process from the same clays. The spalling loss is less per dip than stiff-mud brick but slag penetration and porosity is greater. The volume change in the reheat test is less, and dry-pressed brick have greater resistance to deformation in the load test. They are well adapted for use in boiler furnaces, oil stills, annealing furnaces, forge and welding furnaces, tunnel kilns, periodic kilns, regenerative furnaces, ladles, puddling furnaces, malleable iron furnaces, locomotive arches, and glass tanks. From the production standpoint, the dry-press process has a number of advantages. It is possible to make all the brick of the 9-inch series with a large number of special shapes. One company is now manufacturing 125 different brick by the dry-press method. Tile up to 4 x 12 x 24 and locomotive arch blocks are also being made successfully. Labor costs are lower and up-keep of the equipment is not as great as in the stiff-mud process. No expensive driers are required, and power costs are lower. A better looking product can be made by the dry-press process than by any other method. Other subjects discussed are: (1) amount of water, (2) mixing, (3) pressure to be used, (4) drying and firing. F.P.H.

PATENTS

Process for the manufacture of fired building materials of clay. HUGO GRONROOS. U. S. 1,664,815, April 3, 1928. Process for the production of fired building materials of clay, comprising the steps of preparing a granular annealed material from an admixture of clay and chemical substances adapted to lower the fusing point of the clay, admixing a quantity of the granular annealed material with the clay from which the actual molded units for the building material are produced, molding and pressing the units, and drying, firing, and cooling the same in a kiln in one continuous operation.

Die for hollow tile. EMIL E. BORSENBERGER. U. S. 1,665,342, April 10, 1928. A die for making hollow tiles comprising a die block having a central opening, a bridge across the opening upon the inner side of the die block and comprising longitudinal and transverse arms, and spaced cores carried by the bridge and located within the central opening, the legs of the bridge being located directly in line with the spaces between the cores for the purpose of evenly and uniformly distributing the flow of clay through the interior portion of the die.

Building blocks. F. A. WOOD. Brit. 283,694, March 7, 1928. Bricks and slabs are formed with interfitting dovetailed grooves and projections.

Brick machines. KELLER AND CO. Brit. 284,210, March 21, 1928. Bricks cut off from a continuous bar are delivered obliquely on to frames which are then slued so as to become parallel to the bar upon reaching the conveying device leading to the drying chamber. Bricks cut off a bar are delivered to frames, traversed obliquely to the bar, which pass to a conveyer comprising fixed rails and movable rails operated by unequal cranks whereby the frames are traversed toward elevating means leading to the drying chamber and are gradually slued to a position parallel with the bar.

Refractories

The prevention of disintegration of blast furnace linings. HIMANSU KUMAR MITRA AND ALEXANDER SILVERMAN. *Jour. Amer. Ceram. Soc.*, **11** [5], 278–91 (1928).—Theories and observations on the causes of disintegration of fireclay refractories in blast furnaces are given and a process is developed for improving high iron clays for this use. The

disintegration of refractories in blast furnace linings is initiated by alteration in the iron spots. Ferric oxide is reduced to ferrous oxide at 500°C and hastens the cracking of $2CO$ to CO_2+C, the carbon being retained by the lining. When Fe_2O_3 is converted to Fe_3O_4 the brick will not disintegrate.

Use of the simulative test furnace as a means of making comparative tests of fire brick. G. L. ROGERS. *Jour. Amer. Ceram. Soc.*, **11** [5], 323–29 (1928).—The Navy Simulative Service Test for refractories is described, specifications for the test and the furnace used being given. The simulative service furnace has found application in making comparative tests of different brands of refractories, development of and improvement of standard fire brick, and as a control test for maintaining quality of the product.

Recent developments in firebrick testing. E. E. SAUNDERS. *Bull. Amer. Ceram. Soc.*, **7** [4], 78–82 (1928); *Brick Clay Rec.*, **72** [8], 561–62 (1928).—The past five years have witnessed a tendency toward increase care in the selection of refractories, which has necessitated general interest in the testing and development of refractories in plants and laboratories. In no other field of ceramic endeavor has an appreciation of the scientific and technical research been as general and studies as broad as in the field of refractories. One of the outstanding results of the ambition to develop fundamental information by studying closely the reactions going on under service conditions, and the result of these reactions has been the attempted laboratory duplication of service conditions by means of "simulated" tests. In dealing with materials which cannot be accurately tested and whose every step in manufacture and firing cannot be scientifically controlled, misunderstandings and misapplication of results must be expected if tests involving undeterminable factors are given continued dependence. To arrive at a real solution individual clays must be studied and synthetic bodies composed of clays and other materials, the proportions, grain size, and inherent characteristics of which are known. Dangers from the use of present test reports are discussed. The tests stressed in the U. S. Government Master Specifications for Fireclay Brick are enumerated. Methods for conducting the following tests and limits thereof, together with dangers to be encountered in too great reliability on the results thereof are given: loading test, spalling test, and slag test. E.J.V.

History of the refractories industry. J. D. RAMSAY. *Fuels and Fur.*, **6** [1], 101–102 (1928); *Ceram. Age*, **11** [3], 101–102 (1928).—A paper presented at the joint meeting of the American Institute of Chemical Engineers and American Refractories Institute, December 6, 1928 at St. Louis, Mo. For abstract see *Ceram. Abs.*, **7** [4], 236 (1928). A.E.R.W.

The corrosive action of glass on tank blocks. S. R. SCHOLES. *Fuels and Fur.*, **6** [2], 183–86 (1928).—Accumulated experience shows that no wall or container, of any known material, can be built that is immune to the corrosive action of glass at high temperatures. All of the nonvolatile oxides can be incorporated in the glass itself and become components of the glass. Improvements in physical structure, therefore, must be given great attention. S. describes the effect of molten glass on ordinary tank blocks, illustrating his remarks with diagrams, and concludes that (1) heat is a very important factor in block corrosion and (2) downward facing surfaces are most rapidly attacked, vertical surfaces less rapidly, and upward facing surfaces scarcely at all. The effect of temperature is greatest at the metal line, and here the solution is most rapid. The presence of "salt water" on the surface of the glass, formed from salt cake in the batch, increases this action. The useful life of a tank block is halved by a rise of 150°F in the temperature of the glass. "Upward eating" is due to convection currents and to density increases resulting from solution of the aluminous block material. S. discusses the relative importance of these two factors. He disagrees with the theory that the

alkali of the glass is the active solvent upon blocks, but believes that there is a purely physical basis for block corrosion, depending on the contact at high temperatures with the glass of lower melting point. The two most important factors in endurance are refractoriness and degree of porosity. Efforts are being made to increase these properties. A.E.R.W.

Basic steel campaign in a 3000-pound open hearth. H. D. HIBBARD. *Fuels and Fur.*, **6** [2], 205–207 (1928).—Experiments are described which resulted in the widespread use of basic open-hearth furnaces. Magnesite brick, loose spaeter magnesite, basic open-hearth slag, dolomite, and tar were used as hearth materials. A.E.R.W

Firing properties of refractory fireclay products. A. T. GREEN. *Fuels and Fur.*, **6** [3], 396 (1928).—For abstract see *Ceram. Abs.*, **7** [2], 81 (1928). A.E.R.W.

One-ton acid open-hearth furnace used in making alloy steels. C. E. MEISSNER. *Fuels and Fur.*, **6** [4], 477–78 (1928).—M. describes a one-ton experimental furnace in which regular open-hearth practice can be duplicated. The design is shown by diagrams. The bottom is made of acid bottom sand, using a sand paddle. The fuel consumption is given and the usefulness of the furnace shown by an account of experimental work and tests. A.E.R.W.

Graphite crucibles. ANON. *Brit. Clayworker*, **36** [422], 74 (1928).—Dorset ball clay is the nearest approach to a successful single clay for the manufacture of graphite crucibles. A bond clay must be more refractory for crucibles for melting steel than those for melting brass. For steel the bond clay should fire dense and strong at 1400–1600°C, while for brass 1100°C is sufficient. A crucible made of equal weights of clay and sand is not as strong as if made with the same proportions of clay and graphite. Bodies containing Ceylon graphite are more easily cast than if Alabama graphite is used. Alabama graphite with thin flakes produces the strongest body. Graphite increases the refractoriness of clays. The best results in casting were obtained by addition of about $3^1/_2\%$ sodium hydroxide. Grinding graphite with sodium hydroxide before mixing increased the strength. R.A.H.

Refractories in developmental stage. G. A. BOLE. Amer. Refrac. Inst., *Tech. Paper*, No. 5, March (1928).—We have begun to think of refractories in terms of service. Relatively few service requirements have been met in a specific way. Electric furnace processes are developing only in proportion as the problem of a suitable refractory, product, and design is worked out. The products, which will meet these and many other conditions satisfactorily, have not yet been developed. There are a number of services in which diaspore refractories are standard. Diaspore, however, has the undesirable property of shrinking over a long period of service. The lack of adequate research in the early stages of the development of this refractory has handicapped its early acceptance in many fields where its chemical and mineral constitution would appear to recommend its use. It is only recently that any attempt has been made commercially to calcine the diaspore to a sufficiently high temperature. The use of catalysts (mineralizers) to accelerate the transition of diaspore to a corundum has not been systematically studied. Other types of aluminous refractories being developed at the present time can be grouped under the general head of "mullite." The outstanding properties of all mullite refractories are high refractoriness (P.C.E. value), constancy of volume, and rigidity at high temperatures. As the result of considerable research work, it has been shown that mullite refractories can be made in two general ways: (1) by fusing together in an electric furnace the component constituents, alumina and silica, in the desired proportions casting the melt in sand molds, and refiring the shape so formed to the desired temperature; (2) by securing a mineral which will invert to mullite upon heating. Several common minerals exhibit this property, andalusite, sillimanite, cyanite, and dumorterite. Cyanite is used in two different ways as a base

material; (*a*) as a bond developer, in which case it is finely ground and displaces some of the bond clay in a batch of mix, and (*b*) as a grog, in which case it displaces the nonplastic. Cyanite has been used with success as a bond developer in sagger mixes, but has not been used very largely as a grog in refractory shapes. Cyanite refractories, when properly compounded and fired to a high temperature possess a marked constancy of volume. Brick have shown no linear change on reheating for 5 hours at a temperature of 2800°F. Under load of 25 lbs. per sq. in. at 2750°F, a brick shows less than 2% linear change, while the best grade of flint clay brick will show 4% or more change under like conditions. There are several high temperature insulating materials but none for which satisfactory service is claimed above 2500°F. Practically all metallurgical and industrial operations are carried out much in advance of this temperature, which means that we have not a single insulating material that can hold up in direct contact with the operating temperature. This situation requires that all insulating be used only as a backing-up material. The economies in construction and in subsequent heat losses would be enormous if a highly refractory material with good insulating properties could be found. Under these circumstances it will be seen that the refractory would serve also as the insulation. Of the fifty odd commercial refractories and experimental mixes tried by the Bureau of Mines crew at a power plant in Chicago, the only one which appeared to give marked advantage over hard-fired flint fireclay brick, was a set of samples made of clay-chrome ore mixtures. Two sets of brick were made: (1) 90% clay and 10% chrome, (2) 80% clay. The brick were fired in a laboratory kiln to cone 20 in 3 days. The porosities of the brick ranged from 18 to 22%, the high chrome brick being the more porous. The slag appeared to penetrate the high clay brick deeply but there was considerably less erosion than in the case of the straight fireclay brick of about the same porosity. These brick did not spall. The high chrome brick resisted the slag action remarkably well, there being little or no slag penetration and very little erosion. The erosion which did occur was a skin effect. The high chrome brick, however, spalled. Many bonds have been suggested for chrome ore. The most promising appears to be the lime group. The tendency to spall appears to be an inherent property of chrome spinels caused by a rapid reversible expansion at about 1800°F. Even though chrome or chrome-clay refractories prove to be ideal for resisting slag erosion in the case of a high lime-iron coal ash, the problem of overcoming the spalling tendency will remain a major one for research. The problem, however, is one which could well interest the manufacturer of chrome refractories. F.P.H.

Action of slags on refractory materials. F. HARTMANN. *Ber. deut. keram. Ges.*, 9 [1], 1–15 (1928).—The method of testing is briefly as follows: A cylinder 3 cm. in diameter and 3 cm. in height is cut out of the material to be tested by means of a diamond drill. This is supported within a carbon resistance furnace, the temperature is brought up to the desired point and a definite amount of slag is allowed to fall upon the surface of the material that is being tested; after a definite time interval the refractory is withdrawn from the furnace and the change that has taken place in the volume of the test piece is determined. The greater this change, the more severe is the slagging action on that particular refractory. The change in weight is also determined. About 1500 tests have been carried out to date using various refractories and slags. The slags studied were principally metallurgical slags. The dependence of the slagging action on (1) the cone fusion of the refractory, (2) chemical composition of the slag, (3) pore volume of the refractory was studied. Silica brick and clay refractories were included in the tests. F.P.H.

Coefficient of expansion of zirconium oxide. WILLI M. COHN. *Ber. deut. keram. Ges.*, 9 [1], 16–18 (1928).—The apparatus used was similar to that used by E. Braun, ("Apparatus for the Determination of the Coefficient of Expansion of Solid Bodies," *Z. tech. Phys.*, **7**, 505 (1926)). The effect of the temperature at which the zirconium

oxide had been fired on the coefficient of expansion was determined. Material *A* was fired at 2100°C, *B* at 1440°C, and *C* at 1250°C. The following results were obtained. The linear coefficients given (β) are the mean values between room temperature (20°C) and *t*°C.

$\beta \times 10^{-6}$ Coefficient of Linear Expansion

Temperature *t*°C	Material *A*	Material *B*	Material *C*
40	8.0	5.0	3.85
60	8.0	5.5	3.7
80	8.1	5.55	3.7
100	8.2	5.7	3.7
120	8.35	5.8	3.75
140	8.5	6.0	3.80
160	8.55	6.05	3.8
180	8.6	6.1	3.85
200	8.7	6.2	3.9

These results are compared with those obtained by other investigators. F.P.H.

Properties of raw materials for saggers containing very little quartz. E. KIEFFER. *Ber. deut. keram. Ges.*, **9** [1], 25–28 (1928).—Two types of materials were tested: (1) washed kaolins, (2) sagger clays containing very little quartz. The following properties of the raw materials were determined: (1) drying shrinkage at various temperatures, (2) porosity of various temperatures, (3) fineness, (4) temperature at which deformation takes place, (5) temperature at which deformation of a particular test piece is deformed 2 mm. F.P.H.

Decomposition of refractory brick in a copper reverberatory furnace. ANON. *Eng. and Min. Jour.*, **125** [6], 244 (1928).—A limiting factor in the degree of heat attainable in a copper furnace has been the refractory quality of the silica brick used in the roof arch of the furnace. The fluxing action may be summarized as follows: The pore space of the brick draws up the fusible silicates by capillarity. The slag, formed by the union of the basic dust and acid brick, enters to a distance determined by its fluidity. This is, in turn, governed by the temperature. Where the fluxing is not too rapid, zones appear in the brick. As fresh basic dust is brought up the silica content, especially of the finer sized binder, becomes sufficiently lowered for the bottom of the brick to form droplets in the hot zone. Fragments of silica altered only by heat treatment appear in these drips. The temperature in one of these hot zones was 2600°F. Coarse uncombined particles of silica are found to slough off. The speed of corrosion may be lessened by reducing the amount of dusting. The increased life of refractories due to decreased amount of dusting at the present smelting temperature cannot, however, be used for computing the increased life due to less dusting if the temperature is also raised. It does not seem that cooling the silica bricks with water jackets would increase their life. The best chance of improving present practice lies along the line of still higher temperatures and a refractory of better quality is absolutely necessary. A.J.M.

Refractories for the glass industry. W. J. REES. *Glass*, **4** [2], 52–54 (1927).—Fire clays may contain quartz, feldspar, mica, limonite, and pyrites. Bauxitic clays may contain free alumina. From the equilibrium diagram for the alumina-silica system it can be seen that the refractability decreases steadily as the silica content of alumina-silica or clay-silica mixtures increases, until the mixture of minimum melting point (1580°C) having the approximate composition of silica 91%, alumina 9% is reached. The presence of other fluxes such as mica and feldspar lowers the eutectic temperature and also moves it a little toward the alumina end. Oxide of iron is at times a troublesome impurity in clays and it is undesirable that in clay goods which are to come into actual contact with molten glass it should exceed 2.5%. Segregations of iron oxide are especially undesirable as they may cause such pitting of the surface in contact with

molten glass as to considerably reduce its durability. In general, aluminous clays are more resistant to corrosive action by molten glass but there are other factors which require consideration. Aluminous clays at high temperatures have lower mechanical strength and greater shrinkage than fire clays. A point in favor of moderately siliceous pot clays is their smooth and even wear. The pot wall reduces in thickness uniformly and the layer of glass in contact with it does not become so aluminous as to reduce the rate of diffusion into the rest of the glass. With aluminous pot clays there is a tendency for the formation of stringy glass as the more viscous aluminous layer in contact with the pot wall is drawn into the body of the glass. Sillimanite pot clay mixtures containing 70% or more of sillimanite are free from the disadvantages of aluminous clays. The plasticity of the clay is important in making glass pots. The skilled potter can determine plasticity by the feel of a sample. A combination of the determination of water of plasticity with the Atterberg test is very satisfactory for making comparisons. The water of plasticity is determined in the usual manner by weighing a plastic sample and then reweighing it after drying. In the Atterberg test the clay is placed on a flat plate and kneaded with water until its consistency is such that a U-shaped slot cut in a slab about $^1/_4$ inch in thickness just closes up to a V-section when the plate is gently tapped. The water content or water of plasticity of one portion of this slab is determined. Another portion is then dried until it is just too short to roll out without crumbling and the water content determined. The difference between the two water contents gives the Atterberg plasticity number. A.J.M.

A graphite crucible for use at very high temperatures. M. K. HOFFMANN. *Zeit. f. Elektrochem. u. angew. phys. Chem.*, **33**, 200–202 (1927).—Graphite crucibles made by immersing the ordinary graphite crucible in a $1^1/_2$% colloidal silicic acid or V_2O_5 solution, drying, firing, and sometimes covering the outside with thermonite (an Al_2O_3 preparation) to lessen oxidation are much more resistant to very high temperatures (1800°C or higher) than ordinary graphite crucibles. A crucible immersed 3 times in the colloidal silicic acid solution and dried after each immersion, the outside being covered with thermonite, was held 1 hour and 40 minutes at 1870°C before failure. Such crucibles resisted Al_2O_3 melts much better than ordinary graphite. H.I.

Carbonization in vertical retorts. T. CAMPBELL FINLAYSON. *Gas Jour.*, **180**, 679–86 (1927); *Gas World*, **87**, 533–39 (1927).—A complete description is given of the Woodall-Duckham continuous vertical retorts and their method of operation, together with 6 explanatory figures. The modern vertical retort can produce approximately 3 times as much gas per sq. ft. of ground space as can the modern horizontal retort. By the introduction of steam into the base of the retort a mixed gas can be produced in one operation, and this permits alteration of the B.t.u. value of the gas. Vertical retorts charged with graded coke can also be used as water-gas generators. Details of the W.-D. swelling number tests are given and the appearance of typical tests is illustrated, as well as the interpretation of such tests. An extended discussion is appended. (*C. A.*)

Notes on horizontal settings with special reference to silica retorts. Appendix: Chemical aspects of failures with silica. A. EDWARDS. *Gas Jour.*, **180**, 808–12 (1927).—Volatile Fe compounds from coal (chloride) may react with silicates present in jointing cement and cause concentration of Fe compounds at that point and consequent failure of the joint. Experimental evidence confirms this view. A quartzite cement is proposed which uses an organic glue to give plasticity (instead of clay, etc.). Tests are being conducted with this type of cement. (*C. A.*)

Magnesium brick in the construction of electric furnaces. ANON. *Jour. four elec.*, **36**, 86–87 (1927).—Details for fixing the brick of the lining of the furnaces are considered, using, as binding material, tar, magnesia and clay, magnesia and chalk, and without

any binding material at all. This last is recommended if sufficiently skilled labor is available to fit the brick. (*J.I.M.*)

Aluminous cement for electric furnaces. ANON. *Jour. four elect.*, **36,** 114 (1927).—Heretofore only red bauxite containing 53–58% alumina and up to 20% iron oxide has been considered suitable for preparing aluminous cements for electric furnace linings. Observing certain precautions regarding composition and baking M. Voisin claims that white bauxite containing little iron oxide can be used equally well. (*J.I.M.*)

The electrochemical and electrometallurgical industries in 1927. ROBERT PITAVAL. *Jour. four elec.*, **37,** 6–7 (1928).—Outstanding developments of the world are briefly discussed. (*C. A.*)

The electric furnace and the French fused-quartz industry. J. GEORGES. *Jour. four elec.*, **37,** 10–12 (1928).—The historical development and the difficulties of the process are discussed. (*C. A.*)

The evolution of gases from hot quartz vessels. WILHELM BILTZ AND HELMUT MÜLLER. *Z. anorg. allgem. Chem.*, **163,** 297–301 (1927).—It is shown that silica-glass apparatus dissolves gases in amounts varying with its method of manufacture and subsequent handling, and that these gases are retained with great tenacity even under severe heat treatment. Silica-glass bulbs were surrounded by an evacuated mantle to prevent diffusion of air through their walls, then evacuated, and the increase in pressure within them was determined after different heat treatments. *E.g.*, a bulb which had been worked with a $H_2+C_2H_2$ flame was first heated, while highly evacuated, at 500–900° for 2 days. When it was heated at 1000° for 4 hrs., the pressure within it rose from less than 0.001 mm. to 0.052 mm., and a black carbonaceous coating appeared on its inner walls. In a bulb which had been worked only with H_2 flame the pressure rose to 0.046 mm. under similar heat treatment, and no black coating appeared. In bulbs heated at 635° for 4 hrs. the pressure rose to only 0.0006 mm. If a bulb which yielded a black coating was maintained at 1000° for 110 hrs. while being filled 31 times with O_2, the coating finally ceased to reappear, after which the pressure rose to only 0.009 mm. with 1 hr. heating at 1000°. Curves are given showing the rate of increase of pressure in these bulbs resulting from different methods of heat treatment. (*C. A.*)

Influence of flue dust on the deterioration of fire brick in the Siemens Martin furnace. FRANZ SCHMITZ. *Ber. Ver. deut. Eisenhüttenleute Werkstoff.*, [89], 1–4 (1926).—Chemical examination of worn-out siliceous brick and samples of flue dust show that the deterioration is principally caused by the flue dust from the producer gases. Reduction of silicic acid by hydrocarbons is the chemical process chiefly concerned. The life of the brick is increased by the presence of long gas conduits, as the flue dust is then deposited. This can also be attained, if necessary, by artificial means, by introducing a collecting conduit of large cross-section, or by inserting obstacles. (*J.I.M.*)

Refractory cement. ANON. *Chem. and Met. Eng.*, **34,** 117 (1927).—A new high temperature cement, the basic component of which is chromite, has been placed on the market by the General Refractories Co., of Philadelphia. Its properties are very briefly discussed. (*J.I.M.*)

Silica refractories for coke ovens. A. H. MIDDLETON. *Iron Steel Canada*, **9,** 117–18 (1926).—In a paper read before the North of England Gas Managers' Assn., M. describes the properties of silica refractories as compared with fire clay and semi-silica. The brick consists essentially of a conglomeration of silica fragments set in a matrix of silica and the fluxing agent. These brick show no period of softening over a wide temperature range as occurs with fire clay or semisilica; the silica brick will stand temperatures of at least 1670°C, and maintain rigidity up to the point of collapse, while their heat conductivity is greater than that of fire clay or semisilica. The abnormal expansion of silica is discussed; its practical effect is that the early stages of heating up

should be carried out slowly until a temperature of 600°C is reached. The importance of suitable jointing material is indicated. (*J.I.M.*)

High temperature cement. H. M. THOMPSON. *Trans. Amer. Foundry Assn.*, **34**, 147–49 (1926).—Fire clay as a cement in building furnaces has so little bonding power that the joints of the furnace soon corrode, and collapse may occur. High temperature cement or a ganister made of crushed old fire brick and new fire clay is recommended for all parts exposed to high temperatures. (*J.I.M.*)

Graphic method for determining the coefficients of heat transmission through the walls of structures. R. MEISTERHANS. *Chal. et Ind.*, **8**, 269–74 (1927). (*J.I.S.I.*)

Glass pots. C. ROYER. *Céram. Verrerie*, **47**, 1105 (1927).—The operations necessary after the pot has been manufactured are discussed, *viz.*, drying, preliminary firing, or annealing, before placing in the furnace, placing in the furnace, conditions in the furnace, method of conducting the first melt in a pot. Pots should be dried for a considerable length of time at about 20°, and precautions must be taken to prevent uneven drying. Cracks are frequently caused by raising the pots from their slabs before they are quite dry. Open pots require six months' drying, closed pots two months longer. When thoroughly dry, a pot should "ring" like a fired brick. The process of bringing the pot gradually up to the temperature of the furnace is a delicate one, and varies with the type of pot, whether open or closed. Five types of suitable furnaces are indicated. The flame should never strike the pots, the temperature in the furnace must be absolutely uniform, and multiple gas exits should be provided to ensure proper distribution of the hot gases. A hot chamber should extend below the whole of the bottom of the furnace. The normal time required to place an open pot in the glass furnace is about one-quarter of an hour, and a closed pot, half an hour. Hot spots in the glass furnace must be carefully avoided; the hot gases should be directed toward the roof. After having been withdrawn from the furnace, the pots should be the same color all over. It is a sign of incorrect firing if they are pale in one part and dark in another. (*T.E.C.S.*)

PATENTS

Apparatus for the production of artificial jewels or precious stones. LUDWIG SCHMIDT. U. S. 1,653,022, Dec. 20, 1927. An apparatus for the manufacture of artificial jewels, comprising, in combination, a hollow body of refractory material, a pin extending into a cavity of the body, means for producing a gas flame in the cavity whereby the flame is caused to flow around the pin and a pneumatic device for applying separately suspended particles of pulverized aluminum oxide to the point of the pin, the device comprising a container for providing a supply of compressed gas, a chamber adapted to contain a suspension of pulverized solid aluminum oxide, rotatable means within the chamber for producing the suspension in the chamber and pipes for connecting the chamber with the container of compressed gas and with the cavity of the refractory body.

Recuperator. ERNEST W. WESCOTT. U. S. 1,657,704, Jan. 31, 1928. As a new recuperator, a monolithic recuperator composed of fired ceramic material.

Furnace-wall construction. GEORGE P. REINTJES. U. S. 1,663,280, March 20, 1928. A wall comprising superposed sections of masonry, a horizontal metal supporting member above and spaced from one section and extending longitudinally of and through the overlying section, and tile suspended from the supporting member and underlying and supporting the section of the wall through which the supporting member extends.

Refractory article and method of making. ADOLPH F. HOTTINGER. U. S. 1,663,660, March 27, 1928. A crucible containing carbonaceous material, clay and flux, and having a coating thereon having a constituent composition fusible at approximately the ignition temperature of the carbonaceous material and also having a constituent composition fusible at approximately the vitrifying temperature of the clay.

Furnace wall. GEORGE M. PARKER. U. S. 1,663,773, March 27, 1928. A furnace wall, comprising a permanent portion provided with pockets, a renewable portion made up of a plurality of large, flat tile arranged edgewise and spaced away from the permanent portion so as to form an air circulating passageway between the tile and permanent portion, integral, rearwardly-projecting, reduced shanks on tile provided with flanged head pieces, and elements in the permanent portion of the wall constructed so as to form undercut recesses below the pockets in the permanent portion and adapted to interlock with the head pieces on the shanks when the head pieces are introduced into the pockets and moved downwardly.

Furnace wall. ROBERT A. FORESMAN. U. S. 1,663,977, March 27, 1928. In a furnace wall the combination with a pair of spaced tubular members, of an inner lining member bridging the space between the tubular members and engaging the tubular members at points arranged at one side of a plane passing through the longitudinal center lines of the tubular members, an outer lining member also bridging the space between the tubular members and engaging the tubular members at points arranged at the other side of the plane passing through the longitudinal center lines of the tubular members, the inner and outer lining members being arranged in juxtaposed position with each other, the outer lining member being provided with an aperture, raised portions on the outer member arranged at opposite sides of the aperture, a projection on the inner member extending through and beyond the aperture in the outer member and having a transverse aperture in the portion thereof extending beyond the outer member, and a locking member extending through the aperture in the projection and engaging the raised portions of the outer member.

Brick. NELSON J. LEE. U. S. 1,664,219, March 27, 1928. A furnace bottom including a plurality of rows of oblong bricks laid end to end, each brick having an enlargement formed on the upper surface thereof, the enlargements having curved upper surfaces, and the sides of the enlargements being cut away defining lateral passageways when bricks are positioned adjacent to each other in the formation of the bottom.

Process for the production of magnesium oxide. WILLIAM KOEHLER. U. S. 1,664,630, April 3, 1928. A cyclic process for obtaining magnesium oxide and calcium carbonate from raw dolomite, comprising calcining a mixture of magnesium chloride and raw dolomite to obtain magnesium oxide, calcium chloride, and carbon dioxide, collecting the carbon dioxide, dissolving out and collecting the calcium chloride, separately calcining a second portion of raw dolomite to obtain magnesium oxide and calcium oxide, and collecting the carbon dioxide, treating the magnesium oxide and calcium oxide with calcium chloride and carbon dioxide to form magnesium chloride and calcium carbonate, separating the last-obtained magnesium chloride and calcium carbonate, and utilizing the magnesium chloride for the decomposition of a new supply of raw dolomite as described in the first step of the process.

Process for the production of refractory magnesia compounds. WILLIAM KOEHLER. U. S. 1,664,631, April 3, 1928. A process for the production of an oxide from dolomite comprising treating comminuted uncalcined dolomite with its lime equivalent of a metallic chloride, moderately heating the mixture, dehydrating the mass, dissolving out the calcium chloride formed and calcining the residue.

Coking retort oven. HEINRICH KOPPERS. U. S. 1,664,632, April 3, 1928. An inclined furnace chamber structure for producing gas and coke, comprising in combination: an inclined retort; vertical heating flues arranged alongside the lower end of the inclined retort having their lower ends arranged in an inclined plane substantially parallel to the plane of inclination of the retort; vertical heating flues arranged alongside the upper end of the inclined retort having their lower ends arranged in a substantially horizontal plane; a regenerator below and communicably connected with the vertical flues alongside the lower end of the retort; a regenerator below and communicably

connected with the vertical flues alongside the upper end of the retort, each regenerator being adapted to alternate for inflow and outflow; the regenerator for the vertical flues alongside the lower end of the retort having its upper part arranged stepwise, each step being directly connected with a vertical flue, and the regenerator for the vertical flues alongside the upper end of the retort having the major portion of its upper part in a single horizontal plane for direct connection with its vertical flues; a waste gas collecting channel above the vertical flues and communicably connected therewith, the channel being inclined throughout a portion of its length over the vertical flues alongside the lower end of the retort, and extending horizontally throughout a portion of its length over the vertical flues alongside the upper end of the retort; the furnace structure being formed to provide a charging platform over the horizontally extended portion of the waste gas collecting channel.

Coking retort oven. NATHANIEL G. PARRY. U. S. 1,664,633, April 3, 1928. In a coking retort oven, in combination: a plurality of coking chambers; heating walls contiguous to such coking chambers and respectively constituted of vertical combustion flues disposed into pairs; vertical out-flow channels in each heating wall communicably connected with a pair of combustion flues; duct means extended beneath the coking chambers and communicably connecting the individual vertical out-flow channels of one heating wall respectively with the individual vertical out-flow channels of an adjacent heating wall; and crosswise regenerators parallel with the coking chambers and the heating walls, such regenerators being disposed into in-flow and out-flow operating pairs; each regenerator of each pair being communicably connected with the combustion flues of a pair of adjacent heating walls substantially as specified.

Coking retort oven. JOSEPH VAN ACKEREN. U. S. 1,664,649, April 3, 1928. In a coking retort oven, in combination: a plurality of coking chambers; heating walls contiguous to such coking chambers and respectively comprising vertical combustion flues; vertical out-flow channels communicably connected with a pair of combustion flues; duct means extended beneath the coking chambers and communicably connecting transversely of the intervening coking chambers the vertical out-flow channels of alternate heating walls respectively with the corresponding vertical out-flow channels of intermediate heating walls; and crosswise regenerators parallel with the coking chambers and the heating walls, such regenerators being disposed into in-flow and out-flow operating pairs, both regenerators of each pair corresponding to and being communicably connected with combustion flues of only a single heating wall, substantially as specified.

Process of manufacturing chamotte materials. LUDWIG KERN. U. S. 1,664,689, April 3, 1928. A process of producing grog material suitable for use in chamotte which consists in forming a plastic mass of kaolin, combustible organic matter, a binder, all being in a finely divided state, and water, firing such material at a strong glowing heat, and comminuting the product.

Open-hearth furnace. GEORGE L. DANFORTH, Jr. U. S. 1,665,086, April 3, 1928. In an open-hearth furnace, regenerative chambers, slag pockets, passages connecting the regenerative chambers and slag pockets, passages connecting the slag pockets and furnace ports, and vertically operating dampers adapted to close off the passages connecting certain of the regenerators and the slag pockets, and passages for connecting certain regenerators to certain of the furnace ports independently of the slag pockets.

Fire-tile door frame. MICHAEL LIPTAK. U. S. 1,665,555, April 10, 1928. A door frame, comprising supplemental inner and outer jamb-forming blocks, and supplemental inner and outer arch-forming blocks, the inner arch-forming blocks having terminal extensions resting and slidable upon the outer arch-forming blocks.

Fire wall. MICHAEL LIPTAK. U. S. 1,665,556, April 10, 1928. A wall having a permanent portion comprising a plurality of superposed channel irons extending length-

wise of the wall, rows of fire bricks laid upon the tops of the irons as headers and projecting at the inner side of the wall to form shelves, bricks filling the space between the headers and irons beneath and above the same, including only stretcher courses at the outer portion, and a replaceable portion comprising bricks laid as headers and supported between the shelf-forming headers and abutting the stretcher courses.

Alumina. J. C. SEAILLES. Brit. 283,509, March 7, 1928. Hydrated alkaline earth aluminate is prepared by treating a mixture of aluminium ore and an alkaline earth base with hot or cold water under normal or increased pressure, but in the ratio of 4 molecules of base to 1 of alumina, and preferably with an additional 2 or 3 molecules of base for 1 of silica in the ore. The mixture is treated in a colloidal grinding machine, preferably in an autoclave under pressure. By addition of more alkaline earth base (lime) and prolonging the treatment, more silica is withdrawn as insoluble calcium silicate and silico-aluminate. Calcium aluminate formed is washed to separate most of the lime, and then treated with caustic soda and preferably carbon dioxide, forming sodium aluminate and calcium carbonate. After addition of excess caustic soda, the solution of sodium aluminate is withdrawn, and alumina precipitated by addition of crystallized alumina. The weaker remaining solution of sodium aluminate is used for leaching further calcium aluminate.

Refractory substances. CARBORUNDUM CO., LTD. Brit. 284,732, March 28, 1928. Refractory articles are made of silicon carbide substantially free from iron and other easily reducible metals or compounds thereof. In an example crushed silicon carbide grain is freed from iron by magnetic treatment and by acids, and to 90 parts of this is added bonding material comprising 8 parts pure kaolin and 2 parts feldspar. The materials are mixed with water, molded, and fired.

Terra Cotta

Methods for testing crazing of glazes caused by increases in size of ceramic bodies. H. G. SCHURECHT. *Jour. Amer. Ceram. Soc.*, **11** [5], 271–77 (1928).—Investigations to determine the causes of a type of crazing which develops on certain glazed ceramic wares, some time after firing, revealed the fact that in many cases such crazing is caused by an expansion of the body. This is probably due to the combination of water with the body, while the glaze remains practically constant in size. A body may be tested for this type of crazing by placing the glazed specimens in an autoclave and subjecting them to a steam pressure of 150 to 175 pounds per square inch for one hour. Bodies showing the least tendency to develop this type of crazing are those which have a low porosity, are not very soluble in sulphuric acid, and have a low ignition loss above 110°C.

The absorption of sound by materials. F. R. WATSON. Univ. of Ill., Eng. Exp. Sta., *Bull.*, No. 172, pp. 1–27 (1927).—The object of the investigation was to determine experimentally the absorption coefficients for a number of materials. The theory and

Sound Absorbing Coefficients for Pitch 512

Material	Coefficient (per. sq. ft.)
Open window	1.00
Brick wall	0.032
Brick wall, painted	0.017
Brick, set in cement	0.025
Glass, single thickness	0.027

method of measurement are described at length. The sound-absorbing coefficients for six different pitches, 128–4096, are given for 14 materials usually found in auditoriums. Coefficients for pitch 512 are given for a larger number of materials, among which are brick walls painted, brick set in cement, glass, plaster on wood lath, plaster on metal lath, plaster on tile, and various acoustical plasters. It is concluded that (1) the ab-

sorption is due to the porosity, compressibility, and elasticity; (2) materials finished in the factory are more likely to have laboratory coefficients than those installed on the job, where the skill of the workmen determines the efficiency; (3) painting or decoration is an important consideration; and (4) porous membranes over materials do not have a marked effect. A.E.R.W.

Cracks in roofing tiles. ANON. *Brit. Clayworker*, **36** [431], 359 (1928).—One of the causes of cracks in tiles made by the wire-cut process is due to the heat generated in them as they issue from the machine. The heat affects the colloidal matter in the clay; the plasticity and binding power are reduced and cracks are produced. The cause of the heating is undue friction in the machine; usually the outlet is too small for the size of the barrel and the central shaft is driven too rapidly. A discussion of other types of cracks due to type of clays used and suggested remedies are included. R.A.H.

Cleaners for terra cotta. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, pp. 32–33 (1928).—In connection with its study of the physical properties of architectural terra cotta, the Bureau has investigated the behavior of several cleaners for this material. Sodium hydrosulphite cleans very well without corroding the glaze. Fluosilicic acid cleans satisfactorily and attacks the glaze but slightly. Trisodium phosphate is a good cleaner on standard finishes, but not very successful on glazed finishes. Soap powder is only a fair cleaner and has a tendency to scour and thus roughen the glazed surface. Hydrochloric acid is only fair and slightly corrodes the glaze. Hydrofluoric acid removes the dirt best of any cleaner tried, but also etches the surface finish very badly. R.A.H.

Savings in the use of modern Berlin tile stoves. H. BARLACH. *Keram. Rund.*, **36**, 29–32 (1928). H.I.

White Wares

Artificial vitrifying agents for ceramic bodies. ANON. Bur. Stand., *Tech. News Bull.*, No. 131, pp. 33–34 (1928).—An investigation is being conducted at the Columbus Station of the Bureau to determine the effect of artificial vitrifying agents in ceramic bodies. It is hoped to lower temperature of a given body or to effect a greater vitrification and corresponding translucency at the same temperature. The problem was attacked by choosing certain eutectic mixtures which deform below cone 5. These eutectics prepared as fritted glasses, constitute the source of the artificial vitrifying agents employed in the bodies. A list of the materials between which eutectics were chosen is given together with body composition used in cone deformation study using certain percentages of the prepared frits. R.A.H.

Production of cream-colored bodies. G. H. BROWN. *Ceram. Age*, **11** [3], 77–79 (1928).—There is an increasing demand on the part of the buying public for colored ceramic wares, particularly the cream, ivory, and buff. In the production of cream and ivory table wares these colors are obtained by the use of buff-firing clays. The body of this ware is highly porous. It is more difficult to produce a vitrified cream-colored body. B. investigated the use of rutile as a coloring stain to be added to a white vitreous body. Commercial rutile (2.5% iron) in amounts ranging from 1 to 10% was added to a vitreous floor tile body, 1% producing a pleasing cream color, further additions changing the color to tan, 6% producing the same effect as higher percentages. Titanium oxide (0.5% iron) in varying amounts was added to a characteristic sanitary body which was fired to cone 11 down. Results similar to those obtained with the floor tile were secured. Addition of ferric oxide along with the titanium oxide produced decided changes in color, increasing amounts producing a greenish gray which was unsatisfactory. Elimination of the ball clay from the sanitary ware body improved

the color produced by titanium oxide. Substituting rutile for titanium oxide produced darker colors. Rutile can be used satisfactorily for producing cream-colored, vitreous floor tile. Better colors are secured from bodies which are free from ball clay and low in iron. Ball clay can be used if titanium oxide can be used in place of rutile. The source of rutile is important. It can be pulverized more easily if it is first calcined at a low temperature. The following points are brought out by different manufacturers. Titanium oxide would probably cost twice as much as rutile. Pleasing effects can be obtained with as low as 0.5%. Titanium oxide is difficult to handle as it is sensitive to kiln atmosphere, hard to grind, tends to crystallize, and uncertain in results. With titanium oxide different parts of the kiln give different colors and the iron tends to crystallize more. Rutile cannot be used in terra cotta glaze as it is variable; it is used in underglaze. Rutile overglaze on bricks was susceptible to heat changes. Titanium produces a much stronger effect in a floor and wall tile body as the flint content is reduced. Variations and irregularities in firing caused trouble and showed need for research. A.E.R.W.

The porcelain of Denmark. F. DALGAS. *Ceram. Age*, **11** [3], 80–84 (1928).—D. sketches the origin and development of the Royal Copenhagen Porcelain Works and its successor the Royal Danish Manufactory. After great expansion under Queen Julie Marie, decay began which was followed by a renaissance brought about by Schou and Krog. Schou invented a new oven which permitted higher firing temperatures creating new beauties in the glaze. The high temperature creates the difference between the hard porcelain products of the Royal Danish Manufactory and those of Sèvres, Limoges, and Meissen. The glaze may be a complete feldspar glaze containing no chalk, giving superior qualities to the glaze and to the colors used in the overglaze and the underglaze. Schou and Krog worked essentially with porcelain and underglaze decoration. The Twentieth Century marked a renaissance in overglaze painted porcelain. Gerhard Henning introduced an entirely new method of overglaze decoration. Thorkild Olsen and M. Tidemand perfected gray crackled porcelain. The artistic stoneware produced was a material closely related to porcelain but was harder and fuller. Joachim created the red stoneware comparable to the famous old Chinese sang de bœuf. Celadon porcelain is made possible by the special use of a glaze giving a cool green tone resembling jade. The Royal Porcelain Factory produces 80% of all porcelain made in Denmark. The value of its production in 1926 was 5 million crowns, about seventeen times that of the Sèvres Factory. D. then describes briefly the other porcelain plants of Denmark. The Bing and Gröndahl Porcelain Works is noted for a special overglaze decoration with a series of figures designed by Tergner, also pieces by Kai Neilson, and stoneware by Gauguin. The Danish Porcelain Factory and the "Norden" started as insulator factories but now produce artistic ware, their output being about 2 million crowns. The Copenhagen Crockery Works, a sister of the Royal Copenhagen produces artistic faience, which differs from the old wares of Italy and Persia in having no tin in the glaze and has original designs, often worked with a special blue on a light greenish blue glaze. (Illustrated.) A.E.R.W.

Pottery at New Brunswick produces bathroom fixtures. ANON. *Ceram. Age*, **11** [3], 91–92 (1928).—A description is given of a plant which has been in operation for a year producing porcelain bathroom fixtures. The raw materials include English ball clay, selected clays from Florida and Tennessee, Maine feldspar, and Pa. flint. Eight mechanical presses form the ware. Built-in soap dishes with handles are pressed in one piece. The one-fire process is used, a 40-hour firing to 2400°F. A.E.R.W.

Production of floor tile. P. P. BUDNIKOFF AND V. I. ENDOWITSKY. *Ceram. Age*, **11** [3], 93–95 (1928).—For abstract see *Ceram. Abs.*, **7** [5], 306 (1928). A.E.R.W.

New Westinghouse high voltage insulator plant. I. STANLEY WISHOSKI. *Fuels*

and Fur., **6** [4], 487–94 (1928).—A Harrop tunnel kiln has replaced eight circular kilns and is producing 1.3 times as much ware with only 30% of the former fuel consumption. The kiln, drying ovens, pugmills, presses, etc. are located in a new building 460 ft. long and 270 ft. wide. The equipment is arranged for straight line production. An overhead conveyer is used. W. describes the conveyer, kiln, and the operation of the plant in detail. The insulators are shaped in plaster molds into which the plastic body is forced by rotating tools of the presses. Two continuous conveyer driers and two continuous car type Proctor driers are used. The glaze is applied by dipping. The ware is fired in saggers to 1195°C. The kiln is arranged for operation with oil or natural gas, and accommodates 59 cars. The temperature and draft regulation and the operation of the hydraulic pusher are described. The labor requirements are small. The products are subjected to exacting dielectric, absorption, and other tests. A.E.R.W.

America largest user of English china clay. ANON. *Pottery, Glass, and Brass Salesman*, **37** [8], 27 (1928).—The production of china clay in England for 1927 reached a record output of 997,269 T., just short of the million mark. The highest previous mark was attained in 1912, when there was an output of 963,895 T. including 73,284 of china stone. Figures show that the U. S. uses more than 4 times the amount of the nearest competitor, Belgium.

English porcelain. W. B. HONEY. *Pottery Gaz.*, **53** [610], 644–48 ii (1928).—The art of making and painting porcelain is one with a comparatively short history in Europe: it ceased to be important after the 18th Century. But it is a branch of art with a special importance in two ways. On the technical side, it successfully imitates Chinese porcelain. In Germany the secret of Chinese porcelain was discovered at Meissen in Saxony, early in the century, in 1709. But in England and elsewhere success was limited, until much later, to an imitation of its outward appearance. The variety of these imitations gives English porcelain a special interest. The attractiveness of the best English china depends to a great extent on its material. Chinese porcelain is made of a mixture of two sorts of natural clay or rock, called by the Chinese kaolin and petuntse, and in England china clay and china stone. China stone is a sort of feldspar, which melts at a high temperature and unites with the clay to produce a very hard, vitrified, translucent material. This is glazed with a similar composition which also requires a high temperature for its fusing. At first the chemists and potters believed that the glassy translucent character of Chinese porcelain was due to actual glass in its composition. It was the great merit of the Meissen inventors, Böttger and Tachimhausen, that they recognized that only potters' materials, and not glassmakers', would make true porcelain. But before Böttger's discovery, and for many years after, several kinds of imitation porcelain or soft paste were made by the use of glassmakers' materials, fired at a comparatively low temperature. One of the earliest of these was Medici porcelain. Other kinds were successfully made in France, and it is thought that the earliest English porcelain was made from a French formula. The types of English porcelain considered are Chelsea porcelain, Chelsea "toys," Derby china, Longton Hall china, bone china, Lowestoft, Bristol, Worcester, and Plymouth. The outstanding merits of the chief factories in the half-century (1750–1800) are summed up.

E.J.V.

The manufacture of mosaic tile. GUDMUND DAHL. *Ber. deut keram. Ges.*, **8** [6], 297–321 (1927).—The following subjects are considered: (1) types of European white-firing and colored clays used in making mosaic tile; (2) raw materials used in making this type of tile and the function of these various materials; (3) classes or types of tile; (4) treatment of raw material preparatory to making the body such as grinding, etc.; (5) mixing and pressing the body; (6) glazing, applying the colors, and firing the tile; (7) types of kilns used in this industry; (8) plant outlay of a typical mosaic tile factory;

(9) detailed description of various machines for applying the colors to the tile; (10) description of various other machines and equipment used in making mosaic tile. F.P.H.

Enameling porcelain wall tile. ANON. *Ceram. Ind.*, **10** [4], 398–401 (1928).—A description of the plant of the Superior Enamel Products Co., St. Louis, Mo. This company has entered the field equipped with a new plant producing 15,000 square feet of tile every 8 hours from a double end electric furnace. F.P.H.

Fired color of porcelains. HEINRICH PAETSCH. *Keramos*, **7** [1], T2 (1928).—A discussion of an article by Prof. Berdel on the same subject. See *Ceram. Abs.*, **7** [3], 176 (1928). F.P.H.

Importance of glaze in technical porcelain. ANON. *Chem. Trade Jour. and Chem. Engr.*, **82** [2120], 19 (1928).—A brief description of porcelain manufacture and of some of the physical characteristics of electrical porcelain is given, with remarks on the influence of glazes on physical properties. L.P.C.

Laboratory porcelain. ANON. *Chem. Trade Jour. and Chem. Engr.*, **82** [2124], 124 (1928).—Two types of double walled porcelain funnels are described: (1) a funnel in which the conical part is shaped like an ordinary glass funnel, but is hollow and can be heated by steam or cooled by water; (2) a suction funnel with hollow walls and a perforated plate at the bottom having a system of tubes running through it horizontally, through which steam may be passed. L.P.C.

The German fine ceramics industries in 1927. ANON. *Keram. Rund.*, **36**, 12–14 (1928).—While in general there was increased stabilization in the German fine ceramics industries (including chinaware, electric porcelain, stoneware, and earthenware industries) there were no notable increases in production and in several cases marked decreases. Decreases in amount and value of ware produced in 1927 as compared with 1926 are ascribed to (1) overproduction in 1926, (2) increased competition for export trade from Czechoslovakia, France, and Japan, and (3) increases in tariff rates in many countries to which German ware is exported. Association of German manufacturers to prevent price-cutting and overproduction are noted. Profits in many cases decreased because of increase in wages and lack of demand. H.I.

Rosenthal-Bahn-Isolatoren. K. DRAEGER. *Elektrotech. Zeits.*, **49** [9], 343–44 (1928).—Seven types of porcelain insulators are described together with new types of motor insulators with extra skirts added for high leakage distance, a special type of pin insulator and double skirted suspension insulator of the cementless cone head type. Figures for the mechanical strength and electrical characteristics of the new type of suspension insulators are given. One type has mechanical strength of 11,000 kg. J.T.L., Jr.

North Carolina pyrophyllite as an ingredient in ceramic bodies. G. R. SHELTON. *Jour. Elisha Mitchell Sci. Soc.*, **43**, 13 (1927).—Physical and chemical properties of pyrophyllite make it satisfactory under certain conditions as a constituent of ceramic bodies. Test pieces fired to 1270° developed a faint gray tint. Good glazing was obtained at 1150° with raw Pb glaze. (*C. A.*)

Ceramic casting slips. A. CORNILLE. *Ceram. Verrerie*, **47**, 1103 (1927).—A good casting slip is in a physical state between coagulation and deflocculation. Sodium salts, the least active flocculation agent of all the soluble salts, give the smallest degree of flocculation it is possible to obtain. Porcelain bodies are easy to cast because they contain little soluble matter. Plastic clays are more difficult to cast. Colloidal matter is necessary in a casting slip to prevent segregation of the different grain sizes, but it should not be present in such large quantitites as to hinder the passage of the water toward the mold. (*T.E.C.S.*)

PATENTS

Insulator. GEORGE IRVING GILCHREST. U. S. 1,664,208, March 27, 1928. (1) In combination, in an insulator, a member of refractory insulating material having a portion of substantially cup-shape, a pin structure embodying an elongated insulating tube, metal end members for the tube and a protective covering on it, one of the metal end members being disposed in the cup removed from the side walls thereof, and a body of cement in the space between the cup and the end member in the cup securing the pin to the refractory member. (2) In combination, in an insulator, a member of refractory insulating material having a portion of substantially cup-shape, a pin structure embodying an elongated insulating tube, metal end members for the tube and a refractory tube inclosing it, one metal end member being secured in position in the cup.

Facing tiles. J. R. MALKIN AND MARSDEN TILES, LTD. Brit. 283,775, March 7, 1928. Bullnose and like tiles are formed with one or more girders on the back thereof, each girder comprising two or more sections each of which has at least one end undercut to bind into the cement or plaster.

Pottery molds. W. J. MILLER. Brit. 283,894, March 14, 1928. A mold for use in the manufacture of pottery comprises a standard base member adapted to fit a chuck, and a plaster body member which may be associated in a detachable manner with the standard base.

Insulators. INTERNATIONAL GENERAL ELECTRIC CO., INC. Brit. 283,930, March 14, 1928. To facilitate the removal of air in filling a hollow oil insulator for use with oil-filled electrical apparatus, a passage is provided in the insulator bolt to provide communication between the interior of the insulator and the atmosphere.

Electric insulators. K. A. HAWLEY. Brit. 284,669, March 28, 1928. In insulators of the cap and pin, or pedestal type, a pad of yielding material, such as paper, rubberoid, or other material preferably impervious to moisture and unaffected by the chemicals in cement, is fitted on the pin end in the bottom of the recess in the insulator body.

Pottery shaping. W. J. MILLER. Brit. 284,692, March 28, 1928. Pottery-shaping mechanism comprises means for reciprocating the jigger spindles and adjustable means for causing a period of rotation of such spindles at any time during reciprocation.

Electric insulators. P. R. COURSEY AND DUBILIER CONDENSER CO., LTD. Brit. 284,897, March 28, 1928. An insulating bushing for the terminals of oil-immersed electric apparatus is molded on to both the high-potential and low-potential members. The high-potential member has transverse serrations and squared portions. The low-potential member has a rim or flange bent outwardly round the aperture through which the member passes, the whole rim being embedded in the insulation. The curved form of the rim distributes the electrostatic stress.

Equipment and Apparatus

Electrodeposition of chromium from chromic acid baths. H. E. HARRING AND W. P. BARROWS. Bur. Stand. *Tech. Paper*, No. 346, 36 pp. (1927).—A detailed study is made of the chromic acid plating solution and of the conditions for its operation and control. The three principal types of chromic acid bath which have been developed during the past 70 years are shown to be identical not only in initial behavior, but also in ultimate composition. The recent commercial success of chromium plating is therefore attributed not to any changes which have been effected in the composition of the bath, but to its more careful operation and control. It was found that minor improvements could be effected in the throwing power of chromic acid baths, but that there is little possibility of materially improving this property which has hindered the more general adoption of chromium plating. R.A.H.

Hydraulic classification, its theory, mechanical development, and application to ore dressing. A. W. FAHRENWALD. Bur. Mines, *Tech. Paper*, No. 403, 51 pp. (1927).—Although the fundamental principles of classification have been worked out by others, little has been done in applying these principles to the classification of table feeds, and the practice of classifying table feeds has been largely abandoned in recent years. In the course of the coöperative investigation with the University of Idaho, F. and his associates studied the density of sand and water mixtures in which mineral particles were agitated by rising water in glass and in transparent celluloid columns and pockets. The information gained by these experiments led to the development of a new type of classifier embodying the various elements found necessary. This type of classifier is now in commercial use in mills of the Coeur D'Alene district and elsewhere. Results in practice show that proper classification of sands increases the recovery of valuable minerals by tabling, improves the grade of the concentrate, and increases the capacity of the tables. R.A.H.

Effect of enclosures on direct steam radiator performance. M. K. FAHNESTOCK. Univ. of Ill., Eng. Exp. Sta., *Bull.*, No. 169, pp. 1–37 (1927).—The effect of present types of direct steam radiator inclosures, shields, and covers on the steam condensing capacity of a direct, cast-iron radiator is discussed. Air inlets, air outlets, heights, and grilles of enclosures are given special attention. The results are reported graphically, using the temperatures at the breathing line as abscissae and net pounds of steam condensed per hour as ordinates. The result of each test for a breathing line temperature of 80°F is given in a graphical table for comparative purposes. Among a number of conclusions are (1) the type of air outlet materially affects the performance of a radiator inclosure, and a front outlet, even with a comparatively large area, is less advantageous than a top outlet; (2) increasing the height of the enclosure, in general, increases the capacity of the radiator; (3) by proper design, it is possible to increase the capacity of an inclosed radiator above that of an uninclosed one; and (4) frictional resistance in the air inlet is an important factor. A.E.R.W.

Heat transfer in ammonia condensers. A. P. KRATZ, H. J. MACINTIRE, AND R. E. GOULD. Univ. of Ill., Eng. Exp. Sta., *Bull.*, No. 171, pp. 1–56 (1927).—The coefficients of heat transfer are determined for the bleeder, the double-pipe, and the shell-and-tube types of condenser. Information obtained regarding the effectiveness of the different portions of the cooling surface and the development of optimum and limiting conditions of operation is given. A.E.R.W.

Segregation in storage bins. C. E. BALES. Amer. Refrac. Inst., *Tech., Bull.*, No. 20 (1928).—One of the problems confronting the firebrick manufacturer at the present time is the separation of the coarse particles of clay from the fines in storage bins. Nearly all firebrick plants now crush their clays and store them in bins for wet pan use. Bins are also used to store an adequate supply of clay for stiff-mud and dry-press brick machines. Clay is conveyed to the bins from the screen outlet either by belts or adjustable chutes and as the clay drops into the bins the coarse particles roll out to the edge of the pile, while the fine materials build up in a cone in the center of the bin. In drawing clay from bins in which this condition exists, the charge sometimes contains a very high proportion of coarse particles, while at other times the entire charge resembles flour. It is practically impossible to make a uniform product when such a condition exists and since uniformity in quality, size, and workmanship is of vital importance, it makes the problem of particle separation of considerable interest. From practical experience and research data it is well known that the grain size of the firebrick batch exerts considerable influence on the properties of the finished brick. Brick made from fire clay have a much higher drying and firing shrinkage than brick made from coarse clay of the same type. Therefore particle separation brings about variation in

size. There are two types of storage bins in general use, the rectangular bin with sloping bottom and the cylindrical bin with conical bottom. Where the clay is delivered to the bins on a belt, it is believed that a series of baffles on the sides of the bin to deflect the clay stream would be effective in overcoming particle separation. Where the clay is delivered by an adjustable chute it is possible to get a fairly uniform mix in the bins by maintaining the optimum position of the discharge end of the chute. Some plants using cylindrical bins with conical bottom have tried the following scheme with very good results. The clay is fed from the chute into a large round vertical pipe located directly in the center of the bin. This pipe has openings in it at intervals from the bottom to the top. While filling, the clay falls to the bottom of the tube and enters the bin through the opening, tending to prevent the formation of a cone and the coincident segregation. When the clay is withdrawn from the central pipe it turns over on itself causing a mixing action to take place which corrects segregation. Some plants are using large bins with a number of partitions in them. They are filled separately but emptied collectively. A terra cotta plant was troubled with particle separation in storage bins and they overcome the difficulty by the use of a long, steep chute extending down into and across the bin. The clay pile starts in one corner of the bottom and gradually works up toward the opposite end of the top of the bin, covering the end of the chute as the pile rises and shifts over. Various forms of retarders are being used in storage bins and while they do not prevent segregation during the filling, they do make it possible for the evil to be overcome during the drawing of the clay. A very simple, yet effective, method of helping this condition is to have a small steel cylinder to which angle irons have been bolted, arranged at the discharge end of the chute. As the clay pours from the chute, the angle irons act as paddles and the cylinder revolves, thereby distributing the clay more uniformly over the area of the bin. So far as B. knows the following scheme has not been used to prevent segregation in storage bins, although it is simply a modified agitator such as is used in connection with dry-press brick machines, and the idea might be worked out successfully. A square steel shaft would be placed vertically through the center of the bin and capable of being revolved by gears located above the bin. To this shaft should be attached a steel member, shaped something like an aeroplane propeller which on rotating, would level down the clay and thoroughly mix the coarse particles with the fines and prevent the formation of a cone. It would be necessary for this rotating propeller to climb with the clay and keep on top at all times. This might be accomplished by suitably counterbalancing the propeller-shaped member. Manufacturers who are now troubled with segregation would be amply repaid, for any reasonable expenditure they might make, accomplished by suitably counterbalancing the propeller-shaped member. F.P.H.

A new machine for cleaning glazed ware. ANON. *Keramos*, **6**, 389 (1927).—The apparatus consists of a motor-driven disk to which is attached a flat circular rubber sponge. The sponge is kept wet by means of a jet of water. An aluminum roller is pressed onto the sponge. The glaze is removed by the sponge and the roller removes the slip from the sponge. F.P.H.

Transportation of ceramic raw material. FRIEDRICH RIEDIG. *Keramos*, **7** [1], T1 (1928).—A discussion of various means of transporting ceramic raw materials from the mine and about the plant. Various types of plant locomotives and cable cars are described and illustrated and the advantages enumerated. F.P.H.

Sand setting and devices for setting and classifying sand. II. EDMUND SHAW. *Rock Prod.*, **31** [5], 62–64 (1928).—Elementary forms of settlers and classifiers are described. For Part I see *Ceram. Abs.*, **7** [5], 329 (1928). F.P.H.

Conveyers. ANON. *Brick Clay Rec.*, **72** [7], 488–90 (1928).—The Red Bank Works, at Measham, England, manufacturing brick, pipe, tile, and terra cotta, under the direc-

tion of the Red Bank Manufacturing Co., employs conveying systems throughout its various departments wherever it finds it possible to eliminate manhandling of its product. Overhead and gravity conveyers characterize this clay plant. E.J.V.

Factory design and equipment. XIII. T. W. GARVE. *Clay-Worker*, **89** [4], 288–89 (1928).—The belt conveyer is considered the least troublesome of auxiliary equipment. Full details of types of belts, etc., used in conveying, are taken up. Screw conveyers are discussed and advantages enumerated. Handling of ceramic materials by air or vacuum is touched upon. For previous articles see *Ceram. Abs.*, **7** [4], 232 (1928). E.J.V.

The value of anti-friction equipment. HENRY C. KLEYMEYER. *Clay-Worker*, **89** [4], 290–91 (1928).—A discussion of the use of ball bearing motors and line shaft bearings used in clay plants. The increased use of frictionless bearings has produced a considerable saving for manufacturers. Installations used by various manufacturers are discussed. E.J.V.

General motor applications to dusty conditions. ALBERT E. LAPOE. *Clay-Worker*, **89** [4], 297–301 (1928).—A discussion of the applications made of electric motors in the brick industry. In many cases the motors are operated in dusty conditions. The predominant type of motor used in the industrial field today, the squirrel cage induction motor, is discussed. E.J.V.

Preparation of chromium plating solution. YOGORO KATO, TORU KURAKAMI, AND SINTARO SAITO. *Jour. Soc. Chem. Ind., Japan*, **31** [2], 37B (1928).—Chromium plating solution is generally prepared from CrO_3 solution by its partial reduction or by the addition of $Cr(OH)_3$. The CrO_3 solution is reduced by the electrolysis or by the addition of soluble reducing agents. The authors recommend the treatment of CrO_3 solution with insoluble organic colloids. In the plating, a film of chromic chromate is first formed on the surface of the cathode. Its formation is explained as follows: By the electrolysis, CrO_3 is reduced to $Cr(OH)_3$, which forms this film when the concentration of the hydroxide becomes sufficiently high near the cathode. This was shown by experiments. Results of ultrafiltration and diffusion experiments prove that the chromic chromate solution is not colloidal. Freezing-point depression and electrical conductivity of the solution show that $Cr_2(CrO_4)_3$ resembles $Cr_2(SO_4)_3$ when dissolved in water. Consequently the electric condition through the plating solution is concluded to be electrolytic and not due to cataphoresis as is sometimes inferred. E.J.V.

Studies on the resistivity of chromium plated metals to the action of chemical reagents. TORU KURAKAMI. *Jour. Soc. Chem. Ind., Japan*, **31** [2], 37–38B (1928).—Metallic chromium is in two states, passive and active. The commercial chromium is ordinarily in the passive state, and is highly resistant to acids and alkalis, except hydrochloric acid. The new surface obtained by breaking the commercial chromium is not resistant to acids. Moreover the passive chromium which is in contact with zinc, iron, or some other metals in acids, becomes active and is no longer resistant to acids. The chromium film of the plated metals generally is pinholed and thus the base metal beneath is exposed. Such chromium plated metals are easily dissolved by acids from the causes above explained. The fresh chromium film is in the active state, and not resistant to acids at all. After some time it becomes passive and is not acted upon by the acids. Tables are given showing the experimental results for the action of many acids, alkalis, salts, and the atmosphere on the chromium plated metals. Two important conditions which must be taken into consideration for testing the resistivity of chromium plated metals are (1) length of time after the plating, and (2) pinholes in the chromium film. E.J.V.

Electrical device for mixing solutions. K. HICKMANN AND D. HYNDMAN. Kodak Res. Lab., *Communication*, No. 321; *Chem. and Ind.*, **47**, 238–41 (1928).—The acceptance of electrical methods for following analytical titrations made it inevitable that the chemical engineer should devise similar apparatus for the automatic mixing of solutions. A controlling electrode in a solution is the electrical substitute for a chemical indicator, and indicators may be internal or external. The paper describes an electrical apparatus which works externally, and for that reason escapes limitations inherent in the ordinary methods. H.H.S.

Preventing vibration from machinery with special reference to air compressors. ANON. *Glass*, **4** [2], 57 (1927).—In nearly all industries in which processes are carried on by machinery vibration and noise troubles must be considered. The principal factors are (1) foundation vibrations transmitted through the floors and walls of the building and also pipe connections; (2) primary high frequency air vibrations broadcasted as noise directly from the set; (3) air pulsation in delivery main; (4) air pulsation at inlet orifice. The method to be adopted for any particular set depends upon size, weight, and type of machine. The character of the surroundings and local requirements must be considered. Large compressors are usually mounted upon specially designed concrete foundation blocks. An excavation is made and a concrete slab laid in the bottom. The sides are lined with brick or concrete. Mats of Coresil, a material for absorbing shocks and vibrations are laid upon the bottom slab and the main foundation block constructed upon these mats. The sides of the block are kept clear of the surrounding walls by an air space. Another method is to mount the machine on springs. Special anti-vibrators have been designed and no foundation blocks are required with these. (Illustrated.) A.J.M.

The inspection and maintenance of the thermocouple pyrometer installations in works and laboratories. A. BLACKIE AND C. W. OCKELFORD. *Jour. Sci. Instruments*, **4**, 448–50 (1927).—A general outline of the system of checks adopted at H. M. Fuel Research Station. (*C. A.*)

Chromium plating the German pressed-glass industry. A. BUTZIGER. *Metallwaren Ind. Galvane-Tech.*, **24**, 267–68 (1926).—Details of the plant of Glasfabrik A.-G. Brockwitz for Cr-plating cast-iron glass molds are given and this use of Cr plating is discussed. (*C. A.*)

Lead danger in chromium-plating plants. A. FÖRSTER. *Metallwaren Ind. Galvano-Tech.*, **24**, 288–89 (1926).—CrO_3 forms $PbCrO_4$ with the Pb anodes, tank linings, etc., used in Cr plating, and this $PbCrO_4$ is ever present in Cr-plating plants. While no cases of poisoning have been known various precautions are recommended. (*C. A.*)

Removing the lead danger in chromium-plating plants. E. KRUPPA. *Metallwaren Ind. Galvano-Tech.*, **24**, 310–11 (1926).—The danger of Pb poisoning is avoided by substituting other materials for Pb. Stoneware tanks and suction ducts are used, Al heating and cooling coils, and a special Al alloy has been developed for use as an anode which does not dissolve appreciably and yet permits sufficient current to flow for plating. (*C. A.*)

Removing injurious fumes of electroplating baths. ERICH KRUPPA. *Metallwaren Ind. Galvano-Tech.*, **24**, 408–409 (1926).—The complicated exhausting equipment and loss of electrolyte can be avoided by covering the surface of the bath with a layer of material which is unaffected by the bath, such as paraffin oil, cork particles coated with paraffin, or glass wool soaked in paraffin, etc. The gases evolved do not carry any electrolyte with them after being forced to diffuse through this surface layer. (*C. A.*)

Chromium plating. R. BILFINGER. *Metallwaren Ind. Galvano-Tech.*, **24**, 108–109 (1926).—Polemic with Liebreich who claims that the Langbein-Pfanhauser Werke

process using CrO_3 infringes his patents which nominally cover a bath containing only the reduction products of CrO_3. (*C. A.*)

Chromium plating from commercial standpoint. MAX ALKAN. *Metallwaren-Ind. u. Galvano-Tech.*, **24,** 327–28 (1926).—A. discusses the history of the development of Cr plating and predicts its wide use, especially where large numbers of like objects are to be plated. Liebreich was the first in this field and has the only patents in Germany; the activities of others originate with L. (*C. A.*)

Chromium plating from the commercial standpoint. W. PFANHAUSER. *Metallwaren Ind. Galvano-Tech.*, **24,** 347–48 (1926).—Polemic with Alkan (*cf.* preceding abstract). Salzer worked on Cr plating long before Liebreich entered the field; details of chromium plating were published in his textbook "Galvanotechnik" in 1910. (*C. A.*)

Chromo-plating in Germany. ANON. *Brass World*, **23,** 245 (1927).—The position of chromium plating in Germany as affected by the breakdown of the Liebreich patent is described. (*J. I. M.*)

Anodes for chromium plating. OLIVER P. WATTS. *Amer. Electrochem. Soc.*, Sept., pp. 73–81 (1927).—Various materials including chromium, lead, iron, nickel, ferrosilicon, and certain other ferrous alloys, were tried out in a chromic acid plating bath. It was found that lead anodes are most serviceable for long-continued operation of the bath. (*J.I.M.*)

Characteristics of chromium plating. ANON. *Amer. Machinist*, **65,** 415 (1926).—The properties of deposited chromium, the practical applications of chromium plating, the plating process itself, and the wearing qualities of chromium plate are briefly reviewed. (*J.I.M.*)

Possibilities of chromium plating. WILLIAM BLUM. *Amer. Machinist*, **65,** 948–49 (1926).—The outstanding properties of chromium, the limitations of the plating operations, some of the actual and possible applications, *e.g.*, for gages, reflectors, rules, and scales, are reviewed. (*J.I.M.*)

Chromium plating reviewed. S. FIELD. *Brass World*, **23,** 109–10 (1927).—A brief account of a paper on the history and methods of chromium plating presented before the Electroplaters' and Depositors' Society. (*J.I.M.*)

Advances in chromium plating. W. PFANHAUSER. *Chem.-Zeit.*, **51,** 605–606 (1927).—Chromium deposits obtained at a current density of 5 amp./dm.^{2} may contain 200–250 times their own volume of hydrogen, and as much as 2000 times their volume if obtained with a current density of 20 amp./dm.^{2} This absorbed hydrogen may be removed by treating the metal *in vacuo* on the principle of the electrode sputtering process, whereby light rays emanate from the deposit and the absorbed hydrogen is discharged. Quite large particles may be degassed in 10–15 minutes without a high power consumption. The hydrogen is also removed from the base metal, so that no further danger of fracturing along sharp edges is to be feared. (*J.I.M.*)

Chromium plating. ANON. *Elec. Rev.*, **101,** 125 (1927).—A commercial chromium plating is illustrated. The cost of plating is estimated to be five times that of nickel plating. (*J.I.M.*)

A study of the theory involved in the deposition of chromium. ERIC A. OLLARD. *Electroplaters' and Depositors' Tech. Soc.*, Nov., pp. 5–24 (1927).—The theories of chromium deposition from chromic acid solutions previously put forward by American workers and the German workers, Liebreich and Müller, are discussed and considered untenable. From a consideration of conductivity tests, potentio-metric measurements, migration tests, and chemical analyses, the following is considered to be the mechanism of deposi-

tion: The trivalent chromium compounds present, *e.g.*, sulphate, ionize to give a trivalent ion. The bichromic acid functions as a conducting material, and the chromic salt will give a chromic ion at the cathode and the ion of the corresponding radical at the anode, which reacts with the chromic bichromate, reforming the salt and bichromic acid. The chromic ion is reduced at the cathode, forming first a chromous ion and then the metal; but some of the chromous ions may also escape from the cathode layer, reacting with the bichromic acid to form further quantities of the chromic bichromate. (*J.I.M.*)

A general survey of chromium plating. ERIC A. OLLARD. *Jour. Electroplaters' and Depositors' Tech. Soc.*, **1**, 6–8 (1926).—The practical deposition of chromium from chromic acid baths is outlined, the Liebreich process being favored. Chromium plate is not a satisfactory protection of steel from corrosion, a copper or nickel underlay being necessary. It resists neutral chlorides, *e.g.*, sea-water, and is superior to nickel in resisting tarnish. Various applications are suggested. (*J.I.M.*)

The chromium plating of glass molds. H. W. HOWES. *Glass Rev.*, **3**, 12–13 (1927).—Glass molds plated with nickel or silver are of no use, but chromium-plated molds have many advantages. The cost of chromium plating is very high and the "throwing power" of the solutions used is said to be low. In the U. S. the solutions used are based on Sargent's formula: 1 liter water, 245 g. chromic acid, 5 cc. concentrated sulphuric acid. As an illustration of the value of chromium-plated glass molds, certain German results are quoted. These claim that whereas an ordinary cast-iron mold must be descaled and polished after 1500–2000 pressings, a chromium-plated mold has been used for 80,000 pressings without polishing. Also in Germany the throwing power of the solutions has been improved until even the deepest engravings on the mold can be evenly plated. (*J.I.M.*)

Chromium electroplating. ANON. *Jour. Sci. Instruments*, **4**, 88–89 (1926).—When made of plain manganese-bronze a valve for a filter press had to be replaced every week, but when chromium plated the same valves were still working satisfactorily after 10 weeks' service. Other advantages of chromium plating are indicated. (*J.I.M.*)

Chromium plating. WILLIAM BLUM. *Mech. Eng.*, **49**, 33–35 (1927).—B. discusses the outstanding properties of chromium, which make it a suitable protection chiefly on account of its corrosion-resisting power. Details are given of the bath used in plating, and the three types of deposit which may be obtained, best work being obtained with a chrome acid solution containing a little sulphate, the appropriate temperature being 45°C (113°F) and current density of 10–20 amp./dm.^{2} (*i.e.*, 107–124 amp./ft.^{2}) for a bright deposit. Poor throwing power is a result of lower current density, as in coating irregularly shaped articles. Costs are heavier than other plating processes, due to voltages of 8–10 being needed and insoluble anodes reducing the efficiency. Of the possible applications B. gives printing plates, gages to resist wear, and reflectors to prevent tarnish. It will not replace other forms of plating, although it will serve some purposes better than other metals. (*J.I.M.*)

Plating with chromium. WILLIAM BLUM. *Mech. Eng.*, **49**, 255–57 (1927).—In reply to discussions on his paper, B. states that chromium coatings are harder than any hardened steel tested. Throwing power was influenced by spacing the anodes from the cathodes but increased voltage limits the distance. Deposits of chromium adhere to steel and nickel surfaces, but difficulty has been found with aluminium. Old chromium deposits are best removed by hydrochloric acid before replating to restore the size of gages. Burnishing does not materially improve the dense chromium coatings as it does porous deposits like copper and nickel. Deposits up to 0.005 in. thick are made without cracking or peeling. Thin deposits could be used for facing wire-drawing dies, but not in the finer sizes. (*J.I.M.*)

Notes on chromium plating. ANON. *Metal. Ind.*, (London), **30,** 110 (1927).—Two brief notes: (1) chromium plating of gages at a meeting of the gage committee, Engineering Societies, U. S.; (2) chromium barrel plating. (*J.I.M.*)

Deposition of chromium. S. FIELD. *Metal. Ind.*, (London), **30,** 266–67 (1927).—Abstract of a lecture given at the Northampton Polytechnic Inst., which describes nature of solutions used, effect of current density and temperature, and character of anodes. (*J.I.M.*)

Chromium plating progress. PAUL W. C. STRAUSSER. *Metal. Ind.*, (N. Y.), **24,** 372–74 (1927).—Read before the American Electroplaters' Society. The history of the development of commercial chromium plating is briefly outlined, and S.'s experience with various plating baths recorded. The best results were obtained with a solution containing chromium trioxide 200 g./l., chromic sulphate 5 g./l., and boric acid 3 g./l. Steel anodes were used, with a current density of 100–200 amp./ft.^{2} at 3–4 v. The baths were operated at 40–60°C, according to the metal to be plated, and were agitated during use. (*J.I.M.*)

Chromium-plating developments. CHARLES H. PROCTOR. *Metal Ind.*, (N. Y.), **25,** 331–32 (1927).—A historical survey of the development of chromium plating, and a discussion of the patent position with regard to the U. S. P.'s own experience on 3 baths is recorded, and the following bath is recommended: chromic acid 16 oz./gal., chromic sulphate 1 oz./gal., ferric chromate 1 oz./gal., and boric acid 0.67 oz./gal.; temperature 46–50°C, cathode current density 240 amp./ft.^{2}, ratio of anode to cathode area 1:1, sheet steel anodes. (*J.I.M.*)

Protecting metal surfaces by electrolytic chromium plating. S. JENTSCH. *Metallwaren Ind. u. Galvano-Tech.*, **25,** 147–49 (1927).—The history and development of the protection of metal surfaces by electrolytic chromium plating is considered. The chemical processes during chromium plating are discussed. J. criticizes the results obtained in chromium plating, and states that a thin electrolytic chromium layer cannot satisfactorily protect metals against corrosion. (*J.I.M.*)

Protection of metal surfaces by electrolytic chromium plating. ERIK LIEBREICH. *Metallwaren Ind. u. Galvano-Tech.*, **25,** 207–209 (1927).—A discussion of the properties of chromium layer as obtained by the process of electrolytic chromium plating. (*J.I.M.*)

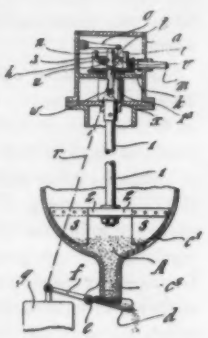
Measurement of moisture movements in building materials. F. L. BARROW. *Jour. Sci. Instr.*, **4,** 475–80 (1927).—Two extensometers for use in measuring the expansion or contraction of building materials under varying moisture conditions are described. Both instruments are mechanical in principle and consist essentially of a lever mechanism, with an optical arm, to magnify the actual movement of the specimen. Movements may be recorded autographically. Both instruments may be used to record length changes with changing humidity of the surrounding air or on immersion in water. (*B.C.A.*)

PATENTS

Conical crushing mill. CHARLES F. SMITH, ARTHUR C. THIELE, AND LLOYD P. WALKER. U. S. 1,663,355, March 20, 1928. A conical crushing mill comprising a rotatably mounted conical concave and a conical crushing head within the concave with its axis at an angle to the axis of the concave, a shaft for such head, a pivotal support for such shaft positioned beyond one end of the concave and a yieldingly mounted support for the opposite end of the shaft positioned beyond the opposite end of the concave.

Valve mechanism for controlling discharge of powdered material and sand from tanks or other receptacles. LEONARD ANDREWS. U. S. 1,665,081, April 3, 1928. For

automatically controlling the discharge of powdered material from the outlet at the lower portion of a tank, mechanism comprising a loaded valve adapted to close the discharge outlet of the tank, a rotary device arranged to rotate in the lower portion of the tank and to be retarded to a greater or less extent by solid material therein, a motor driven cam device and adjustable means arranged to drive the rotary device and to be acted upon by the loaded valve and by the cam device, the arrangement being such that when the mechanism is in use and little or no solid material has collected in the lower portion of the tank, the valve is held by its load in its closed position; but when material collects in the lower portion of the tank, the resistance offered thereby to movement of the rotary device and of the adjusting means, causes the cam device to move the adjusting means in a direction to open the valve, against the action of its load, to a greater or less extent and depending upon the amount of solid material collected in the lower portion of the tank.



Electric furnace for treating ores, shales, etc. FRANCIS E. HATCH. U. S. 1,665,546, April 10, 1928. In an electric furnace comprising a horizontally disposed drum; a lining of refractory material in the drum; heads adapted to close the extremities of the drum; pipes communicating through the heads and extending throughout the drum through the lining; a collector carried at one extremity of the drum and connected with the pipes; and means for causing a current of air to flow through the pipes and collector.

Molding clay articles. J. F. DUKE. Brit. 283,685, March 7, 1928. Relates to the molding of clay articles by means of a concave die having a flexible rubber, etc., lining and consists in stretching and securing a sheet of rubber, etc., over the edge of the convex die.

Kilns, Furnaces, Fuels, and Combustion

Blue and carburetted blue gas. CARL A. SCHLEGEL. *Ceram. Age*, **11** [3], 85–88 (1928).—Blue gas is a mixture of hydrogen and carbon made by the dissociation of steam with hot carbon. Carburetted water-gas is blue gas to which has been added oil gas made by the gasification of oil by heated checkerwork. Their manufacture should not be confused with that of coal gas, which is essentially the destructive distillation of coal, out of contact with the air. S. describes in detail the manufacture of carburetted water-gas, describing the different parts of the machine, its operation, the raw materials used, the chemical reactions involved, the removal of impurities, the extraction of tar, and the storing of the gas. The manufacture of blue gas is described. (Illustrated.)

A.E.R.W.

New decorating kiln fully automatic in operation. I. STANLEY WISHOSKI. *Fuels and Fur.*, **6** [2], 177–80 (1928).—W. describes a new decorating kiln equipped with time and temperature control devices which performs all operation automatically, requiring no attendants except for loading and unloading the ware on cars. The kiln is used in decorating semivitreous ware. It is 162 ft. 8 in. long. High grade refractories are used throughout, alundum being used for lining combustion chambers, andalusite tile in the muffles in the preheating zone and fire brick in the other portions subject to heat. Boiler-plate reinforced with structural shapes is used to hold insulating brick and powder in place. The cars pass through a preheating zone 70 ft. long into a hot zone 13 ft. long. The hot zone is maintained at 1400°F by 8 McKee steel tunnel burners firing into combustion chambers, the temperature being controlled by 4 automatic temperature controllers. The ventilating air is controlled very carefully. A hydraulic system is used

for operating the cars, and is controlled by a time clock. Limit switches are provided on each pusher mechanism so that each operation must be completed before the following operation can take place. A car is charged every 13 or 15 min. The kiln uses 40,000 ft. of natural gas per 24 hrs. and produces 4200–4500 dozens of uniformly good ware. A.E.R.W.

Gas producer operation. V. WINDETT. *Fuels and Fur.*, **6** [2], 217–22 (1928).—The severely close limits of variation permissible in glass furnace practice have made the leaders in this industry particularly keen in taking advantage of improvements in gas producer equipment. W. describes in detail the construction, operation, and method of control of ten gas producers which are used for supplying gas to 2 glass tanks of 1800 T. capacity. The personnel and costs are reported. The use of excess steam is shown to chill the fire in spots and increase the fuel expense, the presence of 1% water vapor in the gas produced increasing the fuel costs 3.5%. The results obtained are described at length, the heat balance being shown graphically. W. points out that gas analyses with aqueous solutions determine the heat of combustion of washed, clean gas, which, in one case, was 14.7 B.t.u. lower than that of the raw gas. The efficiency of the operation was 88.3% calculated on a hot, raw gas basis. Cooling and washing the gas causes a loss in heat of combustion of 18.56% and a further loss at the burner due to the presence of water vapor. A.E.R.W.

Automatic temperature control of industrial heating processes. C. WILHJELM. *Fuels and Fur.*, **6** [3], 400 (1928).—Accurate temperature recording has led to automatic temperature control which must do more than shut off the fuel when the temperature becomes too high and turn it on again when the temperature drops. It must (1) speed up the fuel supply when the demand requires, (2) slow down the fuel supply when the material under treatment requires less heat, and (3) allow time for the heat to penetrate large units. Successful automatic control requires equipment, understanding, and special engineering. The last-mentioned item is often neglected. A.E.R.W.

Industrial heating devices (other than furnaces). I. J. D. KELLER. *Fuels and Fur.*, **6** [4], 461–70 (1928).—K. gives the principles of operation and the features of construction of the following types of burners: (1) Simple pipe burner: slow combustion permits cracking of the hydrocarbons before they are oxidized producing a luminous flame which is useful for heating by radiation. (2) Bunsen type burner: air from the atmosphere is entrained by gas under low pressure, the resulting turbulence causing thorough mixing. (3) Atmospheric ring burner: ring and cluster burners are used because single tube burners are limited in capacity due to their tendency to "snap back" when large tubes are used. Ring burners may have capacities of 435 cu. ft. of 500 B.t.u. gas per hour. (4) Atmospheric disk burner: this will not secure sufficient secondary air unless specially designed. A successful design is given. In all multiple hole burners, the mixing tube and jet must be carefully proportioned. K. describes the use of shutters in connection with atmospheric burners. (5) Cluster burners: cluster burners having pairs of Bunsen tubes whose flames impinge on each other produce high temperature nonluminous flames. (6) Blast type burners: these are used for producing high temperatures. A greater part of the air is supplied by a fan or blower. The burners may be single-jet or disk type. (7) Premix burners: for obtaining very high temperatures and perfect combustion at fan pressures the air and gas are mixed in the fan. The burner nozzle-velocity must be high enough to prevent snap-back. (8) Blow torches: K. describes blow torches operating on denatured alcohol and gasoline. Eight types are described. A.E.R.W.

Improvement in blast furnace construction. J. P. DOVEL. *Fuels and Fur.*, **6** [4], 501–502 (1928).—With the present designs nothing can happen that cannot be repaired from outside without blowing out. Some hearths are now 17 years old. The whole

bosh is now enclosed in metal and does not depend upon its brick work to any great extent. Rebuilding the lining during operation has been made possible by the insertion of a series of rows of bronze cooling plates. A permanent top section was obtained by discarding the brick and substituting a heavy cast-steel jacket lined with cast-iron blocks. Stock distribution is discussed in detail. A.E.R.W.

Coal stripping possibilities in southern and southwestern Illinois. G. H. CADY. Ill. State Geol. Surv., Coöperative Mining Series, *Bull.*, No. 31, Feb. (1928).—The mining of coal by steam and electric shovel has expanded during the last five years due largely to the improvements in machinery. The decrease in the importance of hard layers of rock as deterrents to stripping is shown by the fact that operations have been successful where 5 to 7 ft. of limestone had to be handled. C. discusses the factors bearing on the availability of a deposit, the economic factors governing the success of stripping, and the restoration of waste lands. The occurrences of strippable coal in southern Ill. are described in detail. Several maps accompany the report. A.E.R.W.

Illinois petroleum. GAIL F. MOULTON AND JACKSON S. YOUNG. Ill. State Geol. Surv., *Press Bull.*, No. 14, March (1928).—The paper is accompanied by a structure section from the Martinsville pool in the Western part of Clarke County, Ill., to a well near Middletown in Vigo County, Ind. A map showing the structure of the Devonian limestone drawn with a contour interval of 100 feet is also given. A.E.R.W.

Heat losses in industrial furnaces and their recuperation. R. SCHRUB. *La Ceramique*, **30** [475], 465–71 (1927).—The best way of improving the efficiency of a furnace is to calculate the heat losses, find their causes and reduce them to a minimum. A complete account is given of the theory and practice of controlled combustion. S. gives the heat-balance of a boiler installation and discusses the heat losses from boiler settings and furnaces under the following heads: (*1*) *Sensible heat carried off by the gas.* Combustion calculations are explained in detail. It is concluded that to reduce the losses to a minimum it is necessary to raise the CO_2 content of the exit gases and reduce the difference between their temperature and that of the atmosphere as much as possible. (*2*) *Losses from incombustibles and incomplete combustion.* The disposition of the grate bars has an important effect on the loss in ashes which is usually 5 or 6%, but may be greater. (*3*) *Loss by radiation.* This loss is usually about 5%. It can be reduced by good design. (*4*) *Control of combustion and recuperation of losses.* The principle, operation and use of carbon dioxide recorders are described. It is important to make the masonry as tight as possible, and to charge continuously or at regular intervals. An "air regulation recorder" may be used for checking the work of the fireman. Recuperation may be accomplished by using the products of combustion to heat feed water or to preheat air for combustion. Tube and plate recuperators are described and their efficiencies compared. The added resistance in the gas circuit caused by their use must be overcome by fan equipment. A discussion follows the paper, in which the difficulties involved in the practical application of recuperators to ceramic plants having waste-heat driers are brought out. A.E.R.W.

Noted advance in pulverized fuel firing. ANON. *Can. Chem. Met.*, **12** [3], 75 (1928). —A new short flame burner of British design, for pulverized fuel firing, has been perfected which is claimed to represent a great advance in the whole field of combustion. The main objection to this otherwise highly efficient general principle of firing has been the great length of the flame, which is about 30 feet. As a result a combustion chamber about 50 feet deep is necessary, making little progress possible with pulverized fuel firing in furnaces in general. The new burner on the "turbulent" principle is claimed to give complete combustion, with 17–19% CO_2, in a flame only about 10 feet long. As a result the combustion chamber volume can be reduced 50%, representing a great saving in capital cost, while the possibilities for all kinds of furnace work will be obvious. This new burner will take up to 150,000,000 B.t.u. or 5–6 T. of coal per hour for a single

unit, greatly reducing the number of burners necessary for a given capacity. A solution is claimed for other difficult problems in turbulent burner design, such as low air pressure and power consumption, elimination of "stratification" troubles at the burner tip, absence of complicated parts, one simple adjustment only, and ability to stand the heat. E.J.V.

Practical experience of firing refractory material with oil. FRANK WEST. *Brit. Clayworker*, **36** [431], 370–75 (1928); *Chem. and Ind.*, **47**, 282–83 (1928).—A description of methods used in oil firing beehive and semicontinuous kilns from a standpoint of emergency in case other fuel is not available. R.A.H.

Sources and distribution of major petroleum products in central U. S. E. B. SWANSON AND A. H. REDFIELD. Bur. Mines, *Circ.*, No. 6061, 19 pp. (1928).—This analysis of sources and distribution of major petroleum products in central U. S. completes the series of regional studies pertaining to the distribution of petroleum products, inaugurated by the Bureau of Mines for the purpose of presenting certain fundamental statistics pertaining to the industry. Similar analyses relating to the Pacific and Atlantic coast areas have been published. R.A.H.

Analyses of Indiana coals. W. N. LOGAN. Bur. Mines, *Tech. Paper*, No. 417, 50 pp. (1927).—The Indiana coal field forms part of the larger eastern interior field which covers parts of Ind., Ill., and Ky. The Indiana field covers portions of the western and southwestern parts of the state. The coal-bearing area includes approximately 7000 sq. miles and occurs in 26 of the 92 counties. The coal beds are interstratified with beds of shale, sandstone, fire clay, and limestone. The greater part of the shales are gray, and the proportion of sand to clay in them varies considerably. Classes of coal, geologic conditions, geologic formations, mining methods, production, and transportation are analyzed. A large number of analyses are given which are arranged geographically with respect to counties and towns and are grouped as follows: (1) proximate analysis of moisture, volatile matter, fixed carbon, and ash; (2) ultimate analysis of sulphur, hydrogen, carbon, nitrogen, oxygen, and ash; (3) calorific value or heat of combustion; (4) softening temperature of the ash when such determinations were made. Ultimate analyses are given for three conditions, (1) as received, (2) moisture-free, and (3) moisture- and ash-free. Proximate analyses and heating values are given in two conditions, as received and moisture-free. R.A.H.

Formation of stalactites from glazes in tunnel kilns. EDUARD BERDEL. *Ber. deut. keram. Ges.*, **9** [1], 19–24 (1928).—The formation of drops or stalactites on the roof of the tunnel kiln where a muffle is used in the place of saggers is discussed. The effect of the composition of the glaze on the rate of formation of these drops is discussed. The following recommendations are made to prevent the formation of these stalactites: (1) Raw glazes, especially unfritted lead glazes, should be avoided since free lead oxide is very volatile. (2) The more SiO_2 used in the glaze the less the volatilization of the fluxes. Even the 1–1.5 ratio acid lead silicate is not very volatile. (3) Fritted boric acid is not volatile and for our purpose an entirely harmless fluxing agent. (4) Lead and fritted glazes are decomposed in the firing by the presence of very much lime, and the lime liberates a great amount of the lead as lead oxide. (5) A lime content which is sufficient to bring about this decomposition is made evident by the alkaline reaction of the glaze slip. (6) Alkalis are also liberated by the high lime content of the glaze and are volatilized. (7) Normal white ware glazes containing lead should contain only at the most .25 mols of alkali, .3–.5 mols of lime, and at least 2–3 mols of SiO_2 in order not to volatilize any of the fluxing agents. (8) Lead-free glazes can be made to mature at the correct temperature by the use of boric acid. F.P.H.

Advantages of new type kiln construction. ANON. *Ceram. Ind.*, **10** [4], 416–20 (1928).—A description of the plant of the Fords Porcelain Works at Perth Amboy,

N. J., where 17 Carborundum type kilns have taken the place of 22 periodics. These new kilns have just a little more capacity than the old type, the costly muffle is done away with, and there is a 30% reduction in fuel. Carborundum slabs are used in the kilns and not one was lost during the past 3 years; the first batch of 200 is still in operation. The approximate cost of slabs for the kiln was $2,000. The time of firing was reduced one whole day or from 120 hours to 90 or 95 hours. The roofs of the kilns are insulated and are so built that they form a drying floor for the molds. There have been no repairs on the kiln brick and one kiln was in operation, burning to cone 10 down, for 15 months without a repair of any kind. One big advantage is the fact that there is no flashed ware. F.P.H.

Firing refractories. E. B. PRENTICE. *Ceram. Ind.*, **10** [4], 424–26 (1928); *Brick Clay Rec.*, **72** [8], 563–65 (1928).—The application of stokers to the firing of refractories is described. The use of stokers has cut the fuel costs 40%. In addition to fuel savings, a considerable saving results in labor. Not only does stoker firing lighten the work of the fireman, thereby enabling him to handle more kilns, but the plant is kept clean and no coal or ashes are spread around the whole kiln yard. The small loss of ware is another saving. In several firings the average of resets and broken ware was less than 1% which is a very marked improvement over hand methods. When firing with stokers the entire kiln is under pressure. This accounts for the even distribution of heat and also permits the heat to be easily distributed by varying the size of the floor ports when found necessary. F.P.H.

Ceramic firing in electrically heated kilns. ANON. *Ceram. Ind.*, **10** [4], 452 (1928).—The new electric kiln is of the tunnel type with recuperative chambers for preheating and cooling the charge. Parallel tracks accommodate two rows of cars moving in opposite directions. The heating chamber is in the center of the kiln. In charging, the freshly loaded truck is placed in position before the charging door by a light transfer truck. Both loading and discharge doors are opened and the freshly loaded trucks, one at either end of the kiln and in each row, are pushed in by means of hydraulic pushers. This discharges a fired truck at either end which is removed by the transfer truck. F.P.H.

The use of manufactured gas for firing brick. HERBERT V. KAEPPEL. *Gas Age-Rec.*, **61** [1], 5–8 (1928).—Manufactured gas cannot, of course, hope to compete with a fuel like coal on a price basis, yet the use of gas on brick plants offers advantages over coal which make it a highly desirable fuel to use. There are, for instance, some brick plants today using natural gas at a cost of 60 cents per thousand feet when the B.t.u. equivalent in coal can be purchased at about $^1/_2$ that amount. Major factors affecting the cost of firing brick with which the gas company is concerned are (1) cost of fuel, (2) cost of installation, (3) upkeep of equipment, (4) cost of labor, (5) quality of ware, (6) percentage of first quality brick, (7) time of firing. F.P.H.

The flow of producer gas. ANON. *Gas Age-Rec.*, **61** [1], 9 (1928).—Formulas are given for calculating the size of gas mains to supply definite amounts of fuel for various uses. Upon these formulas, curves can be constructed from which the quantity of coal required to supply gas for any given consumer at a known distance from the nearest trunk main can be easily estimated. The pressure in the trunk main at the connection is known and the required branch of service pipe can be taken from the curves which show pressure drop for various distances and volumes delivered. F.P.H.

Principles and practice of distribution. ANON. *Gas Age-Rec.*, **61** [3], 78–79 (1928).—The flow of gas in mains and the calculation of the diameters of a series of mains and branch lines are discussed. F.P.H.

The future of high temperature carbonization in England. C. H. S. TUPHOLME. *Gas Age-Rec.*, **61** [3], 80–83 (1928).—The high temperature carbonization industries can

produce a solid smokeless fuel for domestic use, and a very greatly extended market is available when the consumers can be persuaded to change over to this type of fuel. The time required will depend upon the rapidity with which the industry prepares to supply the markets. F.P.H.

Firing red brick with oil in tunnel kiln. ANON. *Clay-Worker*, **89** [4], 283–86 (1928). —A description of the new plant of the Hydraulic Press Brick Co., in which the hydraulic press, the tunnel kiln, and method of heat control are the chief features. The present daily production of red face brick is averaging 35,000 but this capacity is to be doubled when needed. The modern equipment used throughout the plant is described. E.J.V.

Draft in round downdraft kilns. CHARLES FINZER. *Clay-Worker*, **89** [4], 291–95 (1928).—A general discussion of the subject from observations made at the author's plants. The flue arrangements at the old and new plants are described. The advantage of an abundance of draft and the handicapping nature of a sluggish draft are discussed. The methods used in solving the draft problem at the Finzer plant are explained, as are the methods of insulating concrete work, and pointers on building good kiln bottoms. A comparison is made of conditions at the old and new plants. E.J.V.

Firing brick with oil and air under pressure. FRANCIS LAMBERT. *Clay-Worker*, **89** [4], 301–302 (1928).—A detailed description of the air burning unit used on the Illinois Brick Co.'s yards for the system of firing their kilns. A summary of practical results obtained by use of this system is given. E.J.V.

The high cost of fuel saving. W. TRINKS. *Glass Ind.*, **9** [4], 84–85 (1928).—The need for fuel saving is not urgent now but soon will be. There are cases where it is cheaper to waste fuel than to save it. The cost of fuel saving is calculated as follows: the cost of the new equipment, including the cost of installation and of removal of the old equipment, minus the cost of salvage of old equipment, and the computed interest depreciation, amortization, also cost due to loss of use during the time of changing over, are added to the cost of possible increases in labor, supervision, and maintenance, and the total is compared with the fuel saving, at present market prices. If the saving sufficiently overbalances the cost items to make the change attractive, the fuel saving equipment is installed. It is always measured in immediate personal gain, saving for future generations never being considered. Examples for this state of affairs are given. These include the return to steam machinery from gas engines because it costs too much to save fuel with the latter. Another glaring example of the high cost of fuel saving is furnished by the electrification of the railroads. Glass-melting furnaces, open-hearth furnaces, and similar high-temperature furnaces waste enormous quantities of heat by radiation, which could be saved by insulation; but the cost of saving this heat is at present prohibitive. Methods of saving fuel are discussed. E.J.V.

The Ceramic Society. ANON. *Pottery Gaz.*, **53** [610], 648ii–48vi (1928).—At the March meeting J. Williamson read a paper on "A New Type of Tunnel Kiln" describing the one installed at a floor tile factory at Poole, Dorset. The new kiln, which may be fired by gas, oil, or coal burnt on open grates, is of the combined, direct-flame, and muffle type. Instead of the flame traveling down the oven in a longitudinal direction, as is usual in tunnel kilns, it takes a transverse course, which might be updraft or downdraft. The flame may be made to alternate from one side of the kiln to the other, so that every part of the truck on which the goods are placed is licked by the flame, thus producing regularity of temperature. The kiln consists of 4 zones, *viz.*, the heating, equalizing, furnace, and cooling zone. The furnace zone is arranged at, or near, the center of the kiln, and on each side of the zone are arranged six or more burners, spaced at a distance equal to the length of a truck, each burner having its own gas and air supply controlled by separate dampers, both the gas and air being under pressure. The gas is supplied by a specially designed producer of simple construction, easy to manipulate

and capable of gasifying coke or coal. The gas and air supply is such that the gas has to pass through the air, and, as each is under positive control, very rapid combustion is possible; but if a long flame is specially desired only a small quantity of air is allowed to pass the air dampers at the bottom, the mixing taking place in the "bag." The flames from the 6 burners, as they issue from the top of the bag walls, are met by a stream of hot supplementary air, and both rise to the crown of the oven, where they meet the flames from the opposite burners. By this means complete combustion is insured, for one common flame extended over a length of the furnace zone of about 40–50 feet. This flame then descended through the goods and under the truck platform where it again divided and flowed through ports into side flues arranged on each side of the tunnel. The outer wall of the flues forming the bag wall, the intense heat which is usually found at that point in most kilns expends itself, not in melting away the brickwork, but in reheating the products of combustion before they pass into the equalizing zone. The equalizing zone consists of a double-vaulted chamber or muffle section which completely encircles the truck, and is constructed of fire bricks or honeycomb section inside and out, so as to present an ample surface for absorbing the heat from the gas on the one side and radiate as much of the heat as possible to the goods on the other. The object of the equalizing zone is mainly to avoid the drop in temperature which would otherwise exist, as the direct flame would necessarily enter the muffle unless other means were taken to reheat the products of combustion. The preheating zone is arranged with exhaust flues on either side of it, of a similar section to those in the furnace zone, which give up the heat to the goods by radiation, conduction, and convection. Special attention has been given to the cooling of the goods with air, by direct and indirect control, and by a system of recuperators arranged on each side of the kiln a supply of very hot air can be passed on to the burners, any surplus being used for drying purposes. The base of the trucks and the brickwork of the oven in the furnace zone can be cooled and when firing at a temperature of 1280°C it is possible to touch the metalwork of the trucks with the bare hand. The encouraging results obtained with this kiln are discussed. E.J.V.

Tunnel kilns. WERNER MORITZ. *Keram. Rund.*, **36**, 19–21 (1928).—For abstract see *Ceram. Abs.*, **7** [5], 314 (1928).— H.I.

Recuperators for enameling kilns. A. JAESCHKE. *Keram. Rund.*, **36**, 23–25 (1928). —Disadvantages of regenerators as compared with recuperators are: (1) change of the flame direction, (2) gas losses in reversals, (3) difficulty in cleaning, (4) greater erection cost. Calculations of flame temperatures for recuperators using gases of specified heating values and definite air admixtures are given. Refractories for recuperators must possess high resistance to slag action (must be basic in character), high heat conductivity, high refractoriness, and must be relatively impervious to gases. Detailed descriptions and drawings of three types of recuperators are given. H.I.

The hydraulic theory of the flow of gas in furnaces. W. E. GROUM-GRJIMAILO. *Glass*, **4** [1], 8–19 (1927).—For abstract see *Ceram. Abs.*, **6** [12], 605 (1927). A.J.M.

Flame and combustion. A. EGERTON. *Nature*, **121** [3036], 10 (1928).—E. deals with the combustion of hydrocarbons below their temperature of ignition and the modifying effects of light dilution and inhibitory substances. He also discusses dissociation and ionization in connection with combustion. C.R.A.

Coal carbonization. ANON. *Nature*, **121** [3041], 201 (1928).—Two books recently published in England are reviewed: "Coal Carbonization at High and Low Temperatures," by J. Roberts is a treatise on the principles and processes of manufacturing coke and semicoke. "Oil and Retortable Materials," by G. W. Halse is a handbook on the utilization of coal torbanite, cannel, and oil shale. C.R.A.

Liquefaction of, and oil formation from, lignite and coal. W. A. DYES. *Chem. Ztg.*, **51**, 853–55, 873–76 (1927).—A review of the economical side of the production of

gasoline from coal. The patent literature, particularly on the Bergius process, is discussed. (*C. A.*)

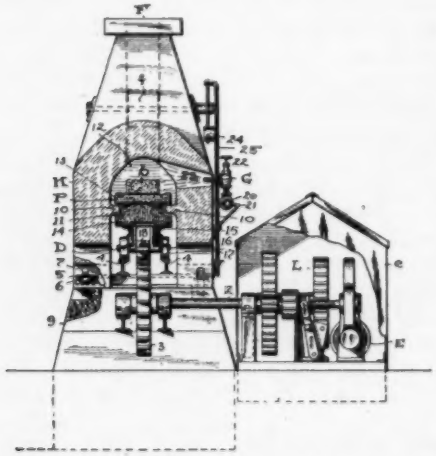
City gas as an industrial fuel. A. I. SMITH. *Gas u. Wasserfach*, **71**, 32–33 (1928).—The application of regeneration to the firing of city gas in industrial ovens is discussed. Two checkerwork regenerators are provided, through one of which the air enters and through the other the exhaust gases escape. These are alternated every half hour by means of a reversing valve. Although such ovens cost about $2^1/_2$ times as much as the usual oven sufficient economies are obtained in some cases to justify their use. (*C. A.*)

A study of the operation and regulation of electric furnaces by means of a diagram. PAUL BERGEON. *Rev. métal.*, **24**, 683–94 (1927).—A mathematical and graphical discussion, reëstablishing and completing de Loisy's formulas and completing Bethenod's diagram (*Rev. gén. elec.*, Nov. 13, **1926**) by combining the transformer diagram with the furnace diagram, thereby showing the effect (which may sometimes be very considerable) of the transformer on the power factor. (*C. A.*)

PATENTS

Process of making mixed gas. HARALD NIELSEN AND JAMES RANKIN GARROW. U. S. 1,654,942, Jan. 3, 1928. A method of making mixed coal gas and producer gas, which comprises degasification of coal at a low temperature by hot producer gas, thereby forming low temperature carbonization coke, dividing the coke into two portions, completely gasifying one portion by blasting with an aeriform or gaseous fluid, passing the generated producer gas into direct contact with the coal to heat the latter to produce the low temperature carbonization coke and coal gas, completely gasifying the second portion of the coke by blasting with an aeriform or gaseous fluid to form producer gas, and mixing the gas produced from the first portion of the coke with that from the second portion.

Tunnel kiln fire box. WILLIAM E. WILSON AND HENRY G. LYKKEN. U. S. 1,662,912, March 20, 1928. A kiln comprising a passage for the movement of ware therethrough, flame chambers at the side of the passage and having floors provided at intervals with flame ports, fuel supply means located beneath the floors and having means for projecting burning fuel upwardly through the ports and into the chambers, whereby the hot products of combustion may pass upwardly to the top of the ware and downwardly therethrough.



Tunnel kiln. HALVER R. STRAIGHT. U. S. 1,663,029, March 20, 1928. In combination, a kiln car having a platform, a ware supporting floor carried by the platform comprising a series of spaced and transverse rows of hollow tile, the tile of each row being arranged in separated groups.

Apparatus for producing clay products. MATTHEW LANG. U. S. 1,663,309, March 20, 1928. An apparatus for making clay products, comprising an arched kiln having an open bottom, an endless track and an endless conveyer close to the open bottom, a series of valved burners arranged at intervals longitudinally of the kiln and a series of power units for the conveyer located at intervals longitudinally of the kiln.

Stoker. NATHAN M. LOWER AND PAUL A. KETCHPEL. U. S. 1,663,636, March 27, 1928. In a locomotive stoker, in combination, a delivery casing adapted for the discharge of fuel into a fire box, means for introducing fuel into the casing through its lower wall, and means for discharging a blast against the fuel for discharging the same from the casing.

Stoker. NATHAN M. LOWER. U. S. 1,663,637, March 27, 1928. In a stoker, a pair of swinging vanes, means for alternately operating them, a variable speed elevator for delivering fuel in the path of the vanes, and means for operating the elevator and vanes in timed relation.

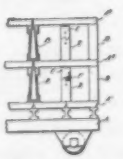
Method for preventing scorification of fire bars, grate surfaces, etc. ROBERT HOPFELT. U. S. 1,663,944, March 27, 1928. A method for preventing the scorification of fire or furnace bars, grates, etc., comprising projecting molten aluminum against the cold work-piece to form upon it a preliminary firmly adherent coating, heating the coated workpiece to approximately the fusion temperature of the aluminum, thereby alloying the inner portion of the coating with the workpiece, the outer portion becoming oxidized and projecting a subsequent quantity of molten aluminum against the coated workpiece while still in its heated state, thereby breaking through the layer of oxide and forming an integral accretion to the inner alloyed portion, producing a coating of any desired thickness.

Electric furnace. IVAR RENNERFELT. U. S. 1,664,132, March 27, 1928. In an electric furnace a refractory, frame-shaped flat body, a ribbon resistor located concentrically along the inner edge of the body, and means for securely clamping and reinforcing the body on the outside edge.

Pottery kiln. ALBERT C. WARD. U. S. 1,664,142, March 27, 1928. An apparatus of the character described comprising a kiln floor adapted to have heat applied therebeneath, supporting tiers for the door defining tortuous passages therebetween and flues interposed between the floor and the tiers.

Tilting hearth tray furnace. ALVIN D. KEENE. U. S. 1,664,749, April 3, 1928. In a furnace, the combination with an annular furnace chamber, and a plurality of hearth trays mounted for movement through the chamber, of means for tilting the trays to effect the discharge of material therefrom, and means carried by a wall of the furnace for returning the trays to a nontilted position.

Means for cooling brickwork of furnaces. ALPHIE E. GETZ. U. S. 1,665,205, April 10, 1928. A furnace, certain of the walls of which are provided with air ducts in proximity to the roof and inclined toward the same, and means for supplying relatively cold air to the air ducts, the latter, due to their inclination, adapted to discharge such air as to cause it to travel interiorly over a part of such walls and roof surface.



Kiln car deck support. CHARLES W. LASCHENSKI. U. S. 1,665,631, April 10, 1928. A self-contained adjustable deck supporting post for a kiln car formed of relatively axially movable refractory parts to vary the effective length of the supporting post.

Tunnel kilns. W. AND A. M. DUCKHAM. Brit. 285,323, April 4, 1928. In the kiln the heating gases are drawn off at one side of the zone of open heating through ports and flues in the walls of the cooling zone, and at the other side through grouped ports leading to ducts, each in damper-controlled communication with the flues in the walls of the preheating zone. Hot air from the wall flues is supplied to the combustion flues through the roof conduit.

Geology

Potash mining in Germany and France. GEORGE S. RICE AND JOHN A. DAVIS. Bur. Mines, *Bull.*, No. 274, 92 pp. (1927).—Methods of mining potash salts in France and Germany are discussed in view of the possible application of similar methods when mining of the deposits in the southwestern part of the U. S. is undertaken. A brief history of the German and French potash industry, a discussion of the geology of the deposits, a short description of the refining of crude salts for export, and an estimate of the cost of production are included. Data were obtained by the author during visits to the German and French potash mining districts in 1911 and 1923 and from various books and articles on the subject, the most important of which are listed in the bibliography at the end of the report. R.A.H.

Preliminary report on fullers' earth deposits of Pulaski County. J. E. LAMAR. Ill. State Geol. Surv., *Rept. of Invest.*, No. 15, March 1928.—A field study of Alexander, Massac, and Pulaski counties has revealed the presence of three deposits of clay in Pulaski County which is similar to the fullers' earth mined at Olmstead, Ill. The report gives briefly the geology of the area with particular emphasis on the Porters Creek formation from which the fullers' earth at Olmstead is obtained. The Olmstead mines are described and illustrated. The potential deposits of fullers' earth are described and recommendations are made for directing exploration work. The results of preliminary tests on various clays from Ill. and elsewhere are given in the two tables. A.E.R.W.

Coalification process. D. J. FISHER. *Jour. Geol.*, **35** [7], 639–46 (1927).—F. shows by means of triaxial diagrams, compiled from analysis data, that the coalification process involves (1) loss in moisture content, (2) loss in oxygen and carbon-oxygen compounds, (3) loss in hydrogen and hydrocarbons. These stages overlap. Diagrams are shown which classify coals according to their composition and show the progressive changes during coalification. C.R.A.

Map of the mineral deposits of the world. D. REIMER AND E. BOHSEN. *Jour. Geol.*, **35** [8], 747 (1927).—R. and B. discuss maps prepared by the Prussian Geological Survey which show the location of all the known mineral deposits in the world, the character of the deposit, content by percentage of useful material, production for 1913 and for the latest available year, and the geological age of the deposit. The legends are in French, German, English, and Spanish. C.R.A.

Geological evaluation of laterite. H. HARRASSOWITZ. *Jour. Geol.*, **35** [8], 748–49 (1927).—H. treats the subject of aluminous alteration products and separates them into siallites (hydrous alumino-silicates such as kaolinite and allophanite) and allites which include bauxite and laterite (hydrates of alumina). C.R.A.

China clay deposits in Ontario. WILLIAM DOUGLAS. *Pottery Gaz.*, **53** [610], 648v (1928).—The china clay deposits on the Mattagami River in northern Ontario may be developed as a result of the extension northward of the Temiskaming and Northern Ontario Railway. The Northern Ontario China Clay Corp., Ltd., has been financed for the construction of a plant eight miles below Smoky Falls. Provided transportation facilities are ready for them in the summer, the company is prepared to dispatch clay and will probably market some clay in any case. The deposits contain fire clay, china clay, and silica sand, and the china clay is believed to be equal to that of Great Britain. In Canada it is largely used in the coating and filling of papers. The fire clay will be used with silica sand in making silica brick, fire brick, gannister brick, and others. It is proposed to turn out various other products, including pigments, colloidal clay, alumina oxide, and Carborundum. E.J.V.

Ukrain kaolin. ANON. *Pottery Gaz.*, **53** [610], 661 (1928).—The Committee of the Institute of Applied Mineralogy and Metallurgy has been investigating the deposits

of kaolin and kaolin factories in the Ukrain, and have found that only one (the Gluchoff deposit in the Vinnitsky district) possesses sufficient investigated reserves of kaolin of high quality, and the Gluchoff kaolin factory is the only one that is working normally. E.J.V.

Building materials of Manitoba. R. C. WALLACE AND L. GREER. *Contract Rec. and Eng. Rev.*, **42** [1], 19 (1928).—An abstract of a report on "The Nonmetallic Mineral Resources of Manitoba," by W. and G., issued recently by the Industrial Development Board of Manitoba. The report contains 93 pages, with numerous maps and photographic illustrations, and covers exhaustively the whole nonmetallic field of the province. Under the three broad headings of structural building materials, fuels, and miscellaneous minerals, W. and G. discuss the possibilities of such resources as building stone, cement rock, clays, and shales for brickmaking, dolomite, gypsum, lime, limestone, monumental and ornamental stone, sands, stucco materials, coal, oil, gas, oil shales, peat, bentonite, feldspar, garnet, lithium, potash, and common salt. Structural and building materials are given the place of first importance and are regarded by the authors as of highest consequence in building up industrial life based on the natural resources at hand. The quarries at Garson, Tyndall, Stonewall, and elsewhere are discussed at length with photographs showing developments. Cement rock quarries at Steep Rock and Babcock are exhaustively considered. A large section is devoted to clays and shales. Surface clays suitable for brick and hollow tile are found at Winnipeg, Portage La Prairie, Edrans, Gilbert Plains, Firdale, and many other points. Carbonaceous shales from Carman and La Riviere have been used. The history of gypsum quarrying in Manitoba is given in detail, with careful descriptions of the present workings. Lime is produced at Spearhill, Stonewall, and Garson, large quantities of which are used by sulphate paper mills. Careful attention has been given to the possibilities of glass sands discovered on Black Island in Lake Winnipeg. These are said to be equal in purity to any on the continent. An occurrence of Dakota sandstone is also of glass sand grade. Copies of the report may be secured by writing the Industrial Development Board of Manitoba, Confederation Life Building, Winnipeg, Man. L.P.C.

Bauxite in 1927. E. C. HARDER. *Eng. and Min. Jour.*, **125** [3], 93 (1928).—Bauxite production in the U. S. showed a decrease in 1927 in comparison with 1926. Of the 1927 U. S. production 54% was used for aluminum manufacture, 24% for artificial abrasives, 21% for the chemical industry, and 1% for minor uses. A new district was opened in southeastern Alabama. The production of Arkansas bauxite decreased because of foreign competition. The imports of bauxite into the U. S. in 1927 were about 355,000 T., most of which came from the British and Dutch Guianas. The amount imported in 1926 was 281,644 T. British Guiana bauxite has a low content of silica and iron oxide. Dutch Guiana bauxite is higher in iron oxide than the British. The leading bauxite producers in Europe are France, Istria, Dalmatia, and central Hungary. Most of the Dalmatian bauxite is shipped to the U. S. for the manufacture of high-alumina cement. A.J.M.

Silica in 1927. E. C. SPEIDEN. *Eng. and Min. Jour.*, **125** [3], 95 (1928).—S. discusses progress in the silica industries from three viewpoints, scientific, technical, and commercial. A.J.M.

Tripoli in 1927. G. V. B. LEVINGS. *Eng. and Min. Jour.*, **125** [3], 97 (1928).—The tripoli industry in 1927 showed an appreciable increase over 1926. The production was 14,000 T. The bulk of the production continues to go to the metal trades, approximately 60% to the foundries, and 30% to the metal finishers. A.J.M.

Diatomite in 1927. P. D. V. MANNING. *Eng. and Min. Jour.*, **125** [3], 100 (1928).—The production of crude diatomaceous earth in 1927 was about equal to the 1926 production. A complete research laboratory has been established by the largest producer

on the Pacific coast. There has been an increase in the use of diatomite as an addition to concrete mix where it adds increased workability and evenness of set. A.J.M.

Feldspar in 1927. F. P. KNIGHT. *Eng. and Min. Jour.*, **125** [3], 101 (1928).—Sales of ground feldspar in 1927 are estimated at 215,000 T. Competition continued to increase. Operations on the whole have been unprofitable. The consumer has demanded a better product and received it at lower cost. Crude feldspar was plentiful throughout 1927. About 12% of the total crude came from Canada. A.J.M.

Chromite in 1927. E. SAMPSON. *Eng. and Min. Jour.*, **125** [3], 104 (1928).—World chromite mining had a year of prosperity. Over 300,000 metric tons were mined. Rhodesia supplied about 210,000 T. The sources of chromite are widely distributed but few are high grade or large. Baluchistan shipped 10,000 T. in the first half of 1927. Greece continues to furnish an important part of the refractory ore to the American market, 21,000 T. being imported in the first ten months. New Caledonia furnished 25,000 to 30,000 T. largely to the European market. In recent years Turkey has produced no chromite. The supply of low-grade chromite ore is large; extensive deposits are found in the Transvaal. Russian ore is again a strong factor in the European market. The extent of the chromite of northwest Montana is still uncertain. Chromite in the American industries in 1927 was distributed as follows: ferrochrome 46%, refractories 41%, chemicals 13%. The outlook for 1928 is good. A.J.M.

Kaolin and white clay in 1927. R. T. VANDERBILT. *Eng. and Min. Jour.*, **125** [3], 105 (1928).—Shipments of china clay and ball clay were larger than in previous years. Domestic production showed about 550,000–575,000 T. About 450,000 T. were imported. The business is on a highly competitive basis with overproduction here and there. The English producers have announced an increase in prices for 1928. No important discoveries of new grades were made in 1927. The outstanding event was the merger of the largest producers of ball and sagger clays in Ky. and Tenn. The use of domestic ball clays has been growing because of the increased demand for ivory-colored ware. This growth is at the expense of both English china and ball clays. A new mine and refining plant started operations in Fla. in 1927. A new bleached or chemically treated clay is being sold to the paper manufacturers. A grade of pyrophyllite from N. C. has interesting ceramic possibilities. The production of American clays has shown an increase in volume for several years past. A.J.M.

Chromite deposit in Indo-China. ANON. *Min. Jour.*, **158** [4804], 7 (1927).—An extensive deposit of chromite is situated in the province of Than-Hoa. A survey, begun in 1915, was completed in 1924. The deposit is estimated to contain 1,700,000 T. of ore. An analysis of ore from one pit shows 11.6% chromite while the ore from another shows 22%. Labor conditions, water supply, and transportation are favorable. A.J.M.

Occurrence of sillimanite in Assam. ANON. *Min. Jour.*, **159** [4811], 926 (1927).—This occurrence is believed to contain 12,000,000 T. of sillimanite. A lease has been taken on the property and attempts are now being made to develop this supply which is somewhat inaccessible. A.J.M.

The texture of bauxites and their origin. JACQUES DE LAPPARENT. *Compt. Rend.*, **185**, 213–14 (1927).—The lighter colored bauxites have been formed from the red by removal of Fe compounds. Bleaching is usually accompanied by increasing crystallinity of the deposit. The whiter portions are generally near the top and are or have been associated with deposits of vegetable material. The structure and associations of the bottoms of bauxite deposits indicate their derivation from beds of decalcified clay probably formed from limestones in temperate climates. Marked decrease in volume has attended the formation of bauxite. H.I.

BOOK

Sands, Clays, and Economic Minerals for All Industrial Purposes. A. L. CURTIS. 4th edition. Chatteris, England: A. L. Curtis, 1928. Price one shilling. H.H.S.

Chemistry and Physics

Some factors influencing the thermal properties of minerals and products of the ceramic industry. WILLI M. COHN. *Jour. Amer. Ceram. Soc.*, **11** [5], 296–306 (1928).—A survey is given of a number of factors which exert an influence upon the following thermal properties of several minerals and ceramic bodies: specific heat, thermal reaction, thermal conductivity, thermal expansion, thermal radiation, etc. The influences in the case of fired and unfired substances are differentiated. A bibliography is presented, which summarizes the work of recent years bearing on the thermal properties of minerals and ceramic bodies. (Translated from the German by Paul Mautz.)

A study of the calcium-sodium ratio of certain waters. R. A. HART. *Jour. Amer. Ceram. Soc.*, **11** [5], 314–16 (1928).—As soluble materials are leached from alkaline soils they may become compact and refractory. This phenomenon is hindered by the presence of calcium or magnesium. Data on calcium-sodium ratios of river waters in different localities are given. It is believed that an unfavorable ratio from the agricultural standpoint would be a favorable ratio with respect to ceramics. The possibilities of use of waters of low calcium-sodium ratio in tempering clays to produce greater density are to be investigated.

Plasticity of clay. LEON E. JENKS. *Jour. Amer. Ceram. Soc.*, **11** [5], 317–22 (1928).—The cause of plasticity of clay is the formation in the moistened clay of a continuous external phase through the action of water in making gelatinous the material that forms the enveloping surface around the non-gelatinous particles and aggregates present in the clay. Peptizing and flocculating effects of electrolytes and organic matter are discussed. A possible method for evaluating the relative plasticity of clays and the results obtained on some commercial clays using this method, are given.

Notes on potassium bisulphate fusions. W. RAYMOND KERR. *Jour. Amer. Ceram. Soc.*, **11** [5], 330 (1928).—The novel proposal in potassium bisulphate fusion of high aluminous material is to previously fuse buttons of potassium bisulphate and previously calcine the sample to be analyzed.

The linear compressibility of thirteen natural crystals. P. W. BRIDGMAN. *Amer. Jour. Sci.* (Series 5), **15** [88], 287–96 (1928).—Data on the linear compressibility of the following minerals are given: andradite, garnet, beryl, apatite, hanksite, tourmaline, quartz, rutile, barite, topaz, jeffersonite, orthoclase, and spodumene. F.P.H.

Oscillation method of X-ray analysis of crystals. JOHN W. GRUNER. *Amer. Mineral.*, **13** [4], 123–41 (1928).—In the oscillation method of crystal analysis a crystal is mounted on an axis and turned back and forth through an angle of about 30° from preferably a known position. A beam of monochromatic X-rays, normal to the axis of rotation, strikes the crystals and is diffracted. The spectra are recorded on a photographic plate. The coördinates for each spot or spectrum are measured. These data are used for the construction of a projection of a new lattice called the reciprocal one with respect to the crystal space lattice. In the projection the indices of each plane producing a spectrum can be read off directly. The advantages of this method especially in the case of crystals with low symmetry are mentioned. It is also possible to distinguish with it members of groups like that of the feldspars, which is extremely difficult, if possible at all, with the Laue and powder methods. Since the discovery of the diffraction of X-ray by crystals in 1912, probably no method of crystal-analysis has promised greater success for the future than the rotation method by Seemann and Polanyi and the oscillation method by Schiebold. While in the rotation method the

crystal is rotated 360° about an axis, in the oscillation method it is turned back and forth about an axis through a limited number of degrees (usually 30°). For the following reasons the oscillation method can be used to great advantage where single crystals, though small, are available: (1) The lengths of the edges of the unit cell of a crystal, as well as the number of molecules in it, can be determined with great precision, regardless of the system of crystallization. Neither the powder nor the Laue method can give us this information in crystals of low symmetry. (2) If the crystal is oscillated in a sufficient number of directions the space group can be determined reliably. The Laue method and, where the symmetry is lower than hexagonal, the powder method, are not to be depended upon for this information. (3) There are often sufficient X-ray spectra recorded on the plates to make important deductions as to parameters of the structure. At present the Laue method is the most widely used for this purpose. Bragg's ionization method is of great importance in special investigations, but ordinarily it would require much more time than could be given to a problem. The application of the method and explanation of the principles involved are given. The graphical methods used in the interpretation of the spectrograms are described. F.P.H.

Anauxite from the Ione formation of California. VICTOR T. ALLEN. *Amer. Mineral.*, **13** [4], 145–52 (1928).—A mineral having the composition of $5H_2O \cdot 2Al_2O_3 \cdot 6SiO_2$ and for which the name ionite was proposed, forms an important part of the Ione formation of California. Recent work shows that it is probably identical with anauxite from Bilin. Evidence is given which indicates that it is formed from biotite or chlorite by loss of magnesium, calcium, iron, and alkalis and with corresponding increase in water. Chemical analyses and optical data are given. An explanation of the occurrence of rutile in clays is offered. F.P.H.

Anauxite, a mineral species, based on material from Bilin, Czechoslovakia. CLARENCE S. ROSS AND WILLIAM H. FOSHAG. *Amer. Mineral.*, **13** [4], 153–55 (1928).—The examination of many clay specimens by R. and F. and their comparison with type material from Bilin has shown that anauxite is one of the most widely occurring clay materials and is especially abundant in many so-called kaolins. This wide occurrence has shown the necessity of a definite knowledge of the chemical and physical properties of anauxite. The Na_2O, MgO, and CaO are present in very minor amounts and are lowest in the most carefully prepared material. It is therefore evident that they are not an essential part of the anauxite molecule, and anauxite is evidently a hydrous aluminum silicate. The anauxite derived from augite gives ratios that are sharply 2:1:3 and this is confirmed by the material secondary to biotite although its ratios are not quite so sharp. It is therefore evident that the correct formula for Bilin anauxite is $2H_2O \cdot Al_2O_3 \cdot 3SiO_2$. Dittler and Hibsch give the following analysis as the result of two closely agreeing analyses: SiO_2 56.56, Al_2O_3 26.09, Fe_2O_3 2.69, MgO 0.11, CaO 0.40, TiO_2 0.38, H_2O 13.58. The physical and optical properties are as follows: crystal system monoclinic; habit vermicular crystals with perfect basal cleavage; cross-section nearly hexagonal in outline; color white; $\alpha = 1.559$, $\beta = 1.564$, $\gamma = 1.565$, $\gamma - \alpha = .006$; extinction parallel in one position, slightly inclined in the other, maximum about 1°30′; orientation as in muscovite $a = Y$, $b = Z$, $c = X$, $2V$ varies from 30° to 42°, mean about 36°; dispersion $\rho > T$; cleavage perfect on (001); luster pearly on (001), subvitreous on prism faces. F.P.H.

Swelling of bentonites and its control. C. W. DAVIS. *Rock Prod.*, **31** [6], 89 (1928).—A study by D. on the effects of different liquids on the swelling of bentonites is reported. The author found that lubricating oil, kerosene, and gasoline prevent swelling and leave a hard granular residue. Dilute solutions of various salt solutions retard swelling but saturated salt solutions are required to obtain the maximum effect, with a resultant firm residue, for each type of bentonite. For some bentonites sodium

chloride gives satisfactory results. Change of temperature from 1 to 94°C accelerates the rate of swelling but has little effect on the final volume of solutions used. Increase of acidity or alkalinity depresses the swelling of bentonite. Equivalent quantities of neutral salts reduce the swelling to about the same degree but the salts with univalent anions (NaCl, KCl, etc.) are slightly more effective than those with polyvalent ions ($BaCl_2$, $AlCl_3$, etc.). F.P.H.

Practical pyrometry. J. R. COLLINS. *Fuels and Fur.*, **6** [3], 301–308 (1928).—C. defines temperature and standard temperature scales, describing the absolute hydrogen scale, the absolute thermodynamic temperature scale and the practical scale defined by the Bureau of Standards. The factors governing the choice of a measuring instrument are outlined and then the different types of pyrometers are classified. The following types of pyrometer are described: mercury in glass thermometers, pressure thermometers, and thermoelectric, resistance, radiation, brightness optical, color, and recording pyrometers. A brief description is given of automatic temperature controllers. Precautions which should be observed in using the different instruments are pointed out. A.E.R.W.

The surface tension of molten metals, with a determination of the capillary constant of copper. E. E. LIBMAN. Univ. of Ill., Eng. Exp. Sta., *Bull.*, No. 173, pp. 1–49 (1928).—In casting operations where sharp outline is necessary, the surface tension of the molten metal, and not its change in volume on cooling, is the governing factor. L. gives a discussion of the general theory of surface tension and then describes in detail the theory of the method of measurement used in the investigation. By means of a special alundum crucible, a direct comparison of the capillary depression of a molten metal at a vertical plane and a capillary tube can be made. In determining the capillary constant of copper, the crucible full of copper is heated in a vacuum by means of a molybdenum winding. The temperature of the copper is determined by measurements of the resistance of the alundum winding. X-ray photographs are used in determining the capillary depressions of the molten copper. A table giving the values of the capillary constant of pure copper at six different temperatures is given. A.E.R.W.

Theory of electrical breakdown of gases at atmospheric pressures. LEONARD B. LOEB. *Jour. Franklin Inst.*, **205** [3], 305–21 (1928).—The general theory of electrical breakdown advanced by Townsend is discussed in detail together with the criticisms made by others of this theory. The recent criticisms are shown to be compatible with Townsend's theory except for one discrepancy. This discrepancy lies in the fact that in the seasoned fields in which breakdown occurs in air the atmospheric pressure and inert gases at low pressure the positive ions are incapable in these fields of acquiring ionizing energy. If the theory is to hold, it is necessary that the potential drop between plain parallel electrodes be more uniform for the spark to pass but must have fields ten times as great as those calculated from a uniform drop. It is shown that such fields are possible. The existence of such fields however requires a finite spark lag interval of 10^{-4} seconds which as yet has not been definitely observed. J.T.L., JR.

Experiments in ultra-violet refractometry. L. C. MARTIN. *Trans. Optical Soc.*, **29** [1], 1–21 (1927–28).—The experiments described have for their object the application of critical angle methods for the refractometry of liquids in the ultra-violet. A thin film of liquid can be held between two quartz hemispheres which are traversed centrally by an approximately parallel beam; the film receives the radiation at the varying angles of incidence resulting on rotation of the system. In this way, analyzing the transmitted radiation with the aid of a quartz spectrograph, the critical angles for definite wave lengths are measured, from which refractive indices can be calculated. The procedure necessary in seeking precise results is discussed, and a series of measurements on glycerine-water mixtures likely to be useful for immersion fluids in ultra-violet

microscopy is given. A set of interesting phenomena of the extinction bands is described and explained. J.T.L., Jr.

A new jelly-strength tester. A. F. Tracey. *Chem. and Ind.*, **47T**, 94–96 (1928).—In the Lipowitz apparatus, a plunger with flat surface rests on the gel, and weights are placed on the upper end of the plunger until it breaks through the jelly surface. This method has the disadvantage that the break of the surface is never very definite; the rupture occurs first as a split, which then spreads and allows the plunger to go through. Experiments were made with plungers of different shapes, and it was found that to get the most definite breaking of the surface, a spherically ended plunger was best. Another point to which attention was directed is the method of expressing jelly strength. Previously it has been the custom to return it as the load per unit of area of plunger end. T. shows that different diameters of plunger give discordant results for the strength of the jelly by this method. On the other hand, if the load per unit of circumference of plunger end be the unit adopted (g. per cm. instead of g. per sq. cm.) the results are concordant for any diameter of plunger. H.H.S.

Scientific and industrial research. Report of the Privy Council Committee. *Chem. and Ind.*, **47**, 241 (1928).—The £623,534 expended last year was to aid investigations on intense magnetic fields, X-rays and crystal structure, chemical reactions at high pressure, calorimetry, humidity measurements, loss of heat from steam pipes, color specifications and measurement, properties of material at high temperatures, low-temperature carbonization, fireproofing of fabrics, the nature of adhesion, and the chemistry of gelatin and allied proteins. Under building research are mentioned C. H. Desch on the mechanism of stone decay, and McBain (now at Stanford) on the nonrigid gels of many building materials. H.H.S.

Ultra-violet radiation in industry. A. A. King. *Chem. and Ind.*, **47**, 301–305 (1928).—Ultra-violet radiation is a form of energy which must eventually come within the province of the chemical engineer, and already finds uses in many branches of industry. The electric arc is used as the source of the radiation. For industrial work it is not economical to use less than 500 volts. Among the applications mentioned, one of ceramic interest is the selection of a particular grade of fluorspar by fluorescence analysis. H.H.S.

Recent developments in microchemical technique. W. Doran. *Chem. and Ind.*, **47**, 308–309 (1928).—In quantitative micro-analysis, which is largely due to the work of Pregl, the quantities dealt with are preferably of the order of 1–10 mgs. The "sensitivity limit" of a reaction is that dilution at which the reaction may be determined with success, but this limit, as determined on a pure substance, is subject to revision in the presence of foreign materials, and effects such as colloid protection, adsorption, or diffusion, may seriously interfere. The microchemical reactions of 72 of the elements are now fairly well known, but new methods are continually being published. H.H.S.

Higher oxidation by electrodeless discharge in gases. J. J. Thomson. Guthrie Lecture. *Chem. and Ind.*, **47**, 312–13 (1928).—When MgO, CaO, or ZnO are placed in a bulb containing oxygen and subjected to electrodeless discharge within a coil of wire through which a rapidly alternating current derived from the discharge of Leyden jars is caused to flow, higher oxides are formed. The element helium is the only substance which failed to oxidize by this method. The method is recommended to chemists as one offering every prospect of effecting all kinds of combinations. H.H.S.

Selective absorption of ions by colloidal clay. A. Demolon and G. Barbier. *Compt. Rend.*, **185**, 149–50 (1927).—A sample of colloidal clay saturated with Ca ions which had been extracted from a brick clay was treated with solutions of the alkali chlorides both alone and in mixtures. The concentration of each salt in all cases corresponded to 2% KCl. Another sample of colloidal clay from which the bases had been

removed was treated with the alkali chlorides alone and in the presence of $CaCl_2$. The experiments indicate that the capacity of clay for taking up cations is a constant independent of the nature of the ions fixed. In the case of mixtures of K, NH_4, and Na ions the Na ions are only weakly absorbed in the presence of the other two. The Ca ion of $CaCl_2$ tends to limit more or less, according to its concentration, the fixation of the alkali ions. By varying the relative concentration of these ions it is possible to modify at will the amount of absorption of each one of them and thus to obtain selective absorption without a membrane. H.I.

Application of viscosimetry to the study of a colloidal clay. A. DEMOLON AND G. BARBIER. *Compt. Rend.*, **185,** 542–45 (1927).—A stable suspension capable of giving a definite viscosity value is prepared from brick clay by decalcification with *N*/5 HCl, washing, agitation in the presence of *N*/40 Na_2CO_3, sedimentation for 24 hours, flocculation by HCl in excess, washing and prolonged dialysis until every trace of chloride is removed, screening through silk bolting cloth, and mechanical agitation for 24 hours. The viscosity is found to increase with increasing concentration following a hyperbolic curve, the increase in viscosity being very rapid beyond a concentration of 55 g./liter. The colloidal clay behaves like most hydrophile colloids. The viscosity decreases rapidly with increase in temperature. The viscosity increases rapidly with increasing amounts of electrolytes to a maximum and then decreases slowly. Studies of permeability show a correspondence between the permeability and viscosity curves with increase in electrolytes up to the point of maximum viscosity. The phenomena observed are ascribed to the production of aggregates of different sizes in the colloidal clay by the addition of electrolytes. H.I.

Formation of crystalline silicates in an aqueous medium under pressure and at high temperatures. W. IPATIEFF AND B. MOUROMTSEFF. *Compt. Rend.*, **185,** 647–49 (1927).—For abstract see *Ceram. Abs.*, **7** [2], 107 (1928). H.I.

Electrolytic deposition of chromium from the solution of chromic acid. YOGORO KATO AND TORU MURAKAMI. *Jour. Soc. Chem. Ind., Japan*, **31** [2], 36B (1928).—The present investigation was carried out to further develop the theory of electrolysis in chromium plating. The results so far obtained show that the current efficiency for the electrolytic deposition of chromium is quite low, being below 30% in most cases and increasing with increasing current density. Hydrogen overvoltage for metals is known in general to increase with the increasing current density. Opinions as to the cause for this overvoltage are not definite. It may be assumed that the overvoltage is due to the accumulation of monoatomic hydrogen. Nernst's formula for the concentration cell may also be applied to the calculation of the concentration of the monoatomic hydrogen. Under this last assumption the values of the concentration of the monoatomic hydrogen at different current densities were calculated from the value of overvoltage. Then these values of supposed concentration of monoatomic hydrogen and the amounts of chromium deposited were both plotted against the values of current density and it was found that both curves were nearly parallel, from which the investigators were lead to conclude that the electrolytic deposition of chromium from chromic acid solution does not take place directly by the loss of electric charges of CrO_4'' or Cr_2O_7'', but indirectly by the reduction, by the monoatomic hydrogen of the film (consisting of chromium oxides) which is formed on the cathode. Superposition of alternating current to the direct current made the current efficiency very low, and this fact favors the above theory. The lowering of the current efficiency with rising temperature is also in its favor.

E.J.V.

Zinc oxide. R. G. DANIELS. *Chem. Trade Jour. and Chem. Engr.*, **82** [2122], 53–54 (1928).—The commonest impurities in zinc spelter are lead, cadmium, and iron. The lead and cadmium may be carried over with the zinc and affect the color of the finished

oxide. Cadmium is most objectionable as even 0.1% will definitely discolor zinc oxide. A process of "sweating" the spelter and a converter type furnace for this is described in detail, as well as a process for the bleaching of off-color oxide. A method for the rapid estimation of lead in zinc oxide is given. Equal weights of pure zinc oxide and the oxide to be tested are dissolved in equal quantities of HCl, then rendered ammoniacal with equal amounts of ammonia and diluted to equal volumes in Nessler tubes. H_2S is then passed through until precipitation is complete. The pure zinc oxide gives a white precipitate to which a standard lead solution is added until the color matches that of the precipitate of the oxide under test. The amount of lead added may then be readily calculated. L.P.C.

Eruptive rocks, their genesis, composition, classification, and relation to ore deposits. B. S. SHAND. *Jour. Geol.*, **36** [1], 91 (1928).—S.'s late publication on the subject of molten silicates is reviewed. C.R.A.

Red sensitive photoelectric cells. C. C. PATERSON. *Nature*, **121** [3037], 58 (1928).—The research laboratories of the General Electric Co. have succeeded in developing a photoelectric cell with a sensitivity more nearly approaching that of the eye than hitherto has been possible. C.R.A.

Production of bubbles from pure selenium. C. E. S. PHILLIPS. *Nature*, **121** [3040], 172 (1928).—Blowing bubbles from pure selenium and their properties of color and cohesion are discussed. C.R.A.

The influence of alkalis on the coagulation of silica and clay suspensions by alkali chlorides. H. B. OAKLEY. *Jour. Chem. Soc.*, pp. 3054–65 (1927).—Certain mixtures of Na, K, Li, or Ca chloride with the corresponding hydroxide, when added in increasing amounts to a purified clay suspension, first flocculate, then fail to flocculate, and finally flocculate the clay again. This phenomenon is shown by kaolin and by SiO_2 coagulated by a small amount of Al_2O_3 but not by pure SiO_2, and it fails only when the suspensions are alkaline. The flocculating powers are, in increasing order: Li, Na, K, and Ca, the last being about ten times as powerful as Na. A maximum appears between a p_H of 9 and 10 in the concentration of Na or Ca chloride required to flocculate clay or kaolin. SiO_2 is flocculated by NaCl or $CaCl_2$ only when the medium is alkaline. The minimum concentration required for flocculation rises rapidly as the alkalinity decreases. SiO_2 is flocculated by 0.0001 *N* $AlCl_3$; greater concentrations give a stable electropositive suspension. The subsequent addition of small amounts of NaOH at first flocculates the suspension and then gives a stable electronegative suspension. Clay is more readily flocculated by $Ca(OH)_2$ than by $CaCl_2$ at equivalent concentrations, if the concentration exceeds 0.003 *N*. Below this concentration $CaCl_2$ is the better flocculant. (*C. A.*)

Titanium white. H. BRAIDY. *Ind. chimique*, **14**, 105–107, 242–45, 290–95, 486–91, 539–42 (1927).—A review of the manufacture, properties, and uses of TiO_2. (*C. A.*)

Equilibrium diagram of the zinc-antimony system. TAKESHI TAKEI. *Sci. Repts. Tôhoku Imp. Univ.*, **16**, 1031–56 (1927).—The discrepancies found by comparing previous diagrams are discussed. The system was reinvestigated by several methods: (1) thermal analysis, using heating curves, (2) electric resistance temperature curves, (3) dilatation-temperature curves, (4) analysis of microstructures, (5) X-ray analysis. The results obtained by these methods are used in constructing a new equilibrium diagram for the system. Three compounds are indicated: Zn_2Sb_2 (44.9% Zn), Zn_4Sb_3 (42.0% Zn), ZnSb (35.2% Zn), the second of which is new. The X-ray analysis, for which no data are given, is said to support the existence of the three compounds. The latter two compounds are formed by a peritectic reaction while the first crystallizes directly from the melt. (*C. A.*)

Preparation of zirconium oxide and the constitution of zirconium salts. PAUL SCHMID. *Z. anorg. allgem. Chem.*, **167**, 369–84 (1927).—From Zr ore (47.5% ZrO_2,

30% SiO_2) the salts can be prepared by heating with sufficient CaO, zirconate being formed. Lumps of ore mixed with lime in the ratio 0.7:1 were fused in an electric furnace (power consumption 12,000 kw. hr. per 1000 kg. of ZrO); the reaction product was heated either with HCl to form oxychloride or with H_2SO_4 for sulphate. Zr oxychloride, $ZrOCl_2 \cdot 8H_2O$, is easily soluble in hot concentrated HCl: 1.03% ZrO_2 at 0°, 2.45% ZrO at 30°, 9.09% ZrO at 68°, HCl at 31–33%. In strong HCl solution the formation of complex compounds was observed. On addition of solid $ZrOCl_2 \cdot 5H_2O$ to HCl oxychloride solution prepared at 0° from ZrO_2 and gaseous HCl (5.26% ZrO_2, 39.32% Cl) the solid salt phase changed gradually; after 6 days it consisted of $ZrOCl_2 \cdot HCl \cdot 5H_2O$. The same substance was prepared by passing gaseous HCl over $ZrOCl_2 \cdot 5H_2O$ (absorption of 44.8%). From HCl oxychloride solution after several months a second complex compound, $ZrOCl_2 \cdot HCl \cdot 6H_2O$, separated in leaflets. Dehydration of $ZrOCl_2 \cdot 8H_2O$ over H_2SO_4 yields the tetrahydrate which cannot be dehydrated without HCl loss; further dehydration to dihydrate is possible in a stream of HCl. The action of dry NH_3 on $ZrOCl_2 \cdot 4H_2O$ causes formation of air-dry $ZrO(OH)_2 \cdot 2H_2O$, insoluble in water, dilute acids or alkalis which give on drying at 110° $ZrO(OH)_2$, metazirconic acid and on ignition ZrO_2. Several structural formulas with coördinative Zr nuclei are proposed as an explanation of these properties and those of the HCl additional compounds with hydroxo groups instead of part of the water of crystallization. A second oxychloride (Endemann, *Jour. prakt. Chem.*, **11**, 219(1875)) could be prepared by precipitation of an alcohol solution of a normal oxychloride with ether as $Zr_2O_3Cl_2 \cdot 3H_2O$. Dehydration by heating gave $Zr_2O_3Cl_2 \cdot H_2O$ and finally $Zr_2O_3Cl_2$. The latter also is formed by heating $ZrOCl_2 \cdot 2H_2O$ in a HCl stream at 230°. $Zr_2O_3Cl_2$ is water soluble; hot HCl gives $ZrOCl_2$ solution. (*C. A.*)

The eutectic freezing-point lowering in binary mixtures. III. E. KORDES. *z. anorg. allgem. Chem.*, **168,** 177–88(1927).—The problem is considered from the standpoint of the phase rule, special attention being given to the case where the eutectic dissociates, and the case in which a complex is formed with the solvent. (*C. A.*)

Research on the thermal decomposition of ferrous sulphate. ERICH GREULICH. *z. anorg. allgem. Chem.*, **168,** 197–202(1927).—Anhydrous $FeSO_4$ was heated in a Pt oven. The pressure of decomposition was measured by the static method. The following values give the temperature in °C, and the corresponding pressure in cm. Hg 251, 0.21; 326, 1.01; 376, 2.04; 433, 3.21; 614.5, 25.40; 634, 32.76; 654, 54.62; 698, 126.3; 235, 0.12; 315, 0.99; 386, 2.84; 482, 7.27; 522, 8.37; 631, 29.6; 645, 58.68; 656, 63.54. By means of Bodenstein's data on the system: SO_3–SO_2–O_2 the composition of the gaseous phase has been determined in each case. The calculated values compare favorably with the actual readings. (*C. A.*)

An automatic recording apparatus for examining and measuring the size of grain of any powder. RUDOLF LORENZ. *z. angew. Chem.*, **40,** 1375–80(1927).—The apparatus is suitable for work in sedimentation, flotation, flocculation, peptization, etc. It consists essentially of a wide vertical glass suspension tube and a narrow parallel tube connected to it through a 3-way cock near the bottom. The wide tube is filled with the suspension and the other with the medium used. Both are illuminated and, after opening the cock at the bottom, a continuous photographic record is made of the decreasing difference between the meniscus levels due to sedimentation. Directions are given for calculating the particle size from the record. (*C. A.*)

Method of determining titanium in bauxite. E. MARTIN. *Chim. et Ind.*, **16**(1926). —The principle of the method is outlined: the titaniferrous solution is reduced with zinc and is then mixed with a measured volume of standard ferric chloride solution. The amount of ferric chloride remaining unoxidized is determined by standard stannous chloride, aided by an iodine solution to indicate the end point. Particular precautions are taken to exclude air during the operations. (*J.I.M.*)

The action of alkalis on clay. H. B. OAKLEY. *Jour. Chem. Soc.*, p. 2819 (1927).—Clay which has been purified by mild acid treatment takes up equivalent qualities of bases up to a p_H of about 9. When the p_H is greater, the amounts removed are in the order lithium, sodium, potassium, barium, calcium. The amount of sodium hydroxide neutralized in the form of soluble compounds is negligible up to p_H 9, but increases rapidly when the alkalinity is greater than this. Clay is assumed to be an insoluble or a colloidal weak acid in direct equilibrium with bases in solution, the salts formed with the various bases being equally insoluble; but unless the alkali is very dilute (p_H9), the clay begins to break down into silicates and aluminates. With sodium these are easily soluble, with calcium they are insoluble. About 1% of the clay is immediately dissolved by N/10-sodium hydroxide; renewal of the alkali rapidly causes the solution of a further 1%. The ratio of silica to sesquioxides in solution increases from 1–6 in four successive treatments. The viscosity and specific volume of coagulated clay show pronounced maxima between p_H 8 and 10 with caustic soda, but not with sodium carbonate at the same p_H values. In base-absorption, water-retention, and imbibitional water, a synthetic aluminosilicate showed considerable analogy with clay. Comparisons are made between kaolin, silica, and bentonite. (*T.E.C.S.*)

Rapid method of determining the free silica in feldspar with the microscope. L. SCHAETZER. *La Ceramique*, **29**, 301 (1926).—Feldspar and quartz are not easy to distinguish optically. On heating to 1200°, however, the feldspar melts, whereas the quartz retains its original structure at about 1300°. In the powdered sample the fused feldspar appears as dark patches under the polarizing microscope with crossed nicols, whereas the quartz grains are light. (*T.E.C.S.*)

BOOKS

Quantitative Electrolytic Analysis. (Quantitative Analyse durch Elektrolyse.) A. CLASSEN. 7th edition, revised by A. Classen and H. Danneel. ix+399 pp. Berlin: J. Springer, 1927. Price 24 RM.—The seventh edition of a standard manual. Comparison of this with early editions shows how widely the principles of electrolytic analysis have been extended. The various forms of electrodes—basin, cylinder, cone, flag gauze cathode, and corresponding shapes of anodes are described. Substitutes for Pt include stellite and Borcher's metal, an alloy of Ni, Cr, Mo, Ag, Cu. Reviewed in *Chem. and Ind.*, **47**, 344 (1928). H.H.S.

The Phase Rule and Its Applications. A. FINDLAY. 6th ed. xv+326 pp. London: Longmans, Green & Co., 1927. Price 10*s* 6*d*.—Reviewed in *Chem. and Ind.*, **47**, 373 (1928), and described as indispensable to serious students of chemistry. A new chapter illustrates the application of the phase rule to the crystallization of individual salts from salt mixtures. H.H.S.

Chemical Encyclopaedia. C. T. KINGZETT. 4th ed. 808 pp. London: Baillière, Tindall & Cox, 1928. Price 35*s*.—An epitomized digest of chemistry and its industrial applications. H.H.S.

Colloids in Industry (L'Etat Colloidal et L'Industrie). W. KOPACZEWSKI. Vol. 2. viii+344 pp. Paris and Liège: Libraire Polytechnique Ch. Beranger, 1927. Price 70 Fr. Reviewed in *Chem. and Ind.*, **27**, 273 (1928).—The volume is divided into 3 parts, dealing with (1) mechanical properties, (2) electrical properties of colloids and their application, and (3) the equilibrium conditions of the colloid state. Under these headings are treated: the separation of colloid micellae, catalysis, adsorption, electrophoresis, stabilization and labilization of hydrosols, and the swelling and syneresis of gels. H.H.S.

Technical Methods of Ore Analysis. ALBERT H. LOW. Tenth edition. xxxiv+348 pp. London: Chapman & Hall, Ltd., 1928. Price 17*s* 6*d*.—Reviewed in *Chem. and Ind.*, **47**, 317 (1928). The tenth English edition of a standard American work. H.H.S.

The Brownian Movement (Brown'sche Bewegung und nicht-flussige disperse Systeme). Edited by W. Ostwald. Dresden & Leipzig: Th. Steinkopf, 1927. Price 6 RM.—A centenary celebration by the German Colloid Society of the discovery by Robert Brown, the botanist, of the movement known by his name. The papers are divided into two classes dealing with (1) aerosols and (2) solid disperse systems, and said to be of great interest and exceptionally well illustrated. Reviewed in *Chem. and Ind.*, **47**, 317 (1928). H.H.S.

The Nature, Origin, and Interpretation of the Etch Figures on Crystals. A. P. HONESS. xiii+171 pp., 16 figures, and 79 original photographs of etch figures. John Wiley and Sons, New York, 1927. Reviewed in *Amer. Mineral.*, **13** [4], 157 (1928). F.P.H.

Elements of Optical Mineralogy. Part II. Description of Minerals. 2nd Edition. N. H. AND A. N. WINCHELL. xvi+424 pp. with 333 text figures. Entirely rewritten and much enlarged by A. N. W. John Wiley and Sons, New York, 1927. Price $5.50. Reviewed in *Amer. Mineral.*, **13** [4], 156 (1928). F.P.H.

PATENTS

Process for purifying and bleaching heavy spar. KARL EBERS. U. S. 1,663,159, March 20, 1928. Process of purifying and bleaching heavy spar consisting in mixing the ground spar with manganese dioxide and heating this mixture with hydrochloric acid and washing.

Red lead. CONSORTIUM ELECTRO-CHIMIQUE DE FRANCE. Brit. 283,898, March 14, 1928. A paste of spongy, finely-divided metallic lead, obtained as by electrolysis, is slowly dried at a temperature rising progressively to approximately 200°C prior to being roasted to obtain red lead. A mixture of lead monoxide and peroxide is obtained by the drying operation, and it is stated that by controlling the temperature and duration of the roasting operation litharge or red lead may be obtained.

Manufacture of pure hydrate of alumina. G. H. HULTMAN. Swed. 63,648, Sept. 6, 1927. Siliceous raw materials are decomposed in H_2SO_4, the dissolved iron sulphate is reduced to $FeSO_4$ and $CaCO_3$ is added to the solution. Al_2O_3 and $CaSO_4$ are precipitated while $FeSO_4$ is obtained in solution and separated. The residue is leached with water till complete solution of the $CaSO_4$ leaves a pure hydrate of Al_2O_3. (*C. A.*)

General

Changes in permissible list of explosives. Bur. Mines, *Report*, Serial No. 2854, Feb. 1928.—No explosives were withdrawn up to Jan. 31, 1928 from the active list of permissibles as approved prior to June 30, 1927. R.A.H.

Geophysical methods of prospecting. A. S. EVE AND D. A. KEYS. Bur. Mines, *Tech. Paper*, No. 420, 26 pp. (1927).—Detection of ore bodies under ground depends on the difference between the properties of the body and of the surrounding medium. This difference is sometimes magnetic, particularly when iron ore is present or when magnetite is distributed throughout some particular material the detection of which is desired. Under other conditions sulphite ore body may have electrochemical properties the result of oxidation by surface water, and then the system behaves like a battery. In addition to these separate magnetic and electrical properties, there are the combined electromagnetic effects, common to all bodies but varying for different kinds, which depend on electrical conductivity, dielectric constant, and magnetic permeability. Hence there arises a variety of possible detectors, some of them using direct or continuous current and some of them alternating current with a wide range of frequencies extending upward through the audible to radio frequencies, and involving principles of induction and capacity. Important differences in density lead to gravitational methods which use either a pendulum or the torsion balance. Again, where there are materials differing in

density and in elasticity the velocity of the sound or of the shock waves varies with the different materials, and detection may be made by seismic methods; *i.e.*, the waves caused by an explosion, refracted or reflected from various strata are detected by a quake recorder or seismometer. This report is written for geologists, mining engineers, and others who desire a concise and simple explanation of the more important physical prospecting that at present is being applied by scientific institutions and private companies. The different methods described are all based on recognized physical principles, but the interpretation of the results obtained from such surveys depends of course on the knowledge and experience of the geologists and physicists consulted. The best methods to use at any particular place will depend upon the geological structure of the region and the type of mineralization one is looking for. Experience will be an important factor in reaching a decision. The subject has been divided into 4 separate groups. Under each group the main topics are briefly described with the physical principles involved and a diagram is given illustrating simple theoretical cases.

R.A.H.

Directory of commercial testing and college research laboratories. Bur. Stand., *Misc. Pub.*, No. 90 (1927). Revised edition. R.A.H.

Practical cost methods for manufacturers of clay products. V. W. H. COMPTON. *Ceram. Age*, **11** [3], 89–91 (1928).—C. states that it is difficult to arrive at a satisfactory cost unit and outlines the units used by the majority of the companies in different ceramic lines. (*1*) *Sanitary earthenware.* The "washdown bowl" is adopted as unit. Its weight is used as a weight unit in the slip and shipping departments and the outside volume of its biscuit and glost saggers used as displacement units in the biscuit and glost kilns. (*2*) *Tile.* The sagger has been adopted as a unit. By dividing the cost per sagger by the number of pieces in a sagger, the cost per piece is obtained. (*3*) *Bricks.* The usual unit is one thousand bricks. (*4*) *General ware.* The list value method is used but is not as good as determining the actual cost per dozen. (*5*) *Electrical porcelain.* While manufacture is continuous, the products are special. Charges must be distributed to each job or order. (*6*) *Outline of procedure.* Financial, cost, and operating statements are prepared every 30 days. Books of original entry should be posted to the general ledger. The production records will be converted to units. The cost per unit in each department, the cost of sales, and profit from sales should be calculated. Typical cost forms are given. For preceding abstracts see *Ceram. Abs.*, **7** [5], 327 (1928).

A.E.R.W.

Summary of investigations at the Bureau of Standards. ANON. *Ceram. Age*, **11** [3], 112–16 (1928); see *Ceram. Abs.*, **7** [3], 195 (1928). A.E.R.W.

Heat transmission through boiler tubes. H. O. CROFT. Univ. of Ill., Eng. Exp. Sta., *Bull.*, No. 168, pp. 1–55 (1927).—The purpose of the investigation was to obtain heat transmission data under conditions similar to those existing in an actual water-tube type of boiler and to study the phenomena of water circulation under the same conditions. Steam was generated in a boiler having a single water tube. The steam generated was condensed and weighed and used for computing the heat absorbed by the tube. The heat was obtained by burning illuminating gas and passing the products of combustion parallel to the axis of the tube. Sufficient data were obtained to correlate the heat transmission coefficients with the rate of flow of the gas, the gas temperature, the velocity of the water in the tube, the temperature of the water, and the temperature of the tube. Tests were also made with a tube coated with scale which was taken from actual boiler service. A.E.R.W.

A simple method for determining stress in curved flexural members. B. J. WILSON AND J. F. QUEREAU. Univ. of Ill., Eng. Exp. Sta., *Circ.*, No. 16, pp. 1–24 (1928).—Although the ordinary flexure formula, which gives reliable values for primary stresses

in straight beams or flexural members, is still widely used in the design of curved flexural members, it gives values for stress that may be much too small. The Winkler-Bach formula, commonly used, gives results that agree with values found by experiment. It is, however, difficult in application, the analytical method of evaluating the property Z of a cross-section being very complicated except for circular and rectangular sections. The straight beam flexure formula can be used if reliable values for a correction factor K are available. The object of the investigation was to determine such values for a number of common sections. These are reported in the circular. The stress computed by the corrected straight beam formula applies only to the extreme fibers of the members. Since the significant stress usually occurs at an extreme fiber, the method offers a simple, satisfactory, and practical means of designing curved flexural members. In appendices are given (1) expressions for the section property Z, (2) a method for the graphical determination of Z by the line polygon method, and (3) the derivation of the Winkler-Bach formula. A.E.R.W.

The Franco-German trade agreement and the ceramic industry. ANON. *La Ceramique*, **30** [475], 475–85 (1927).—An account is given of the articles in the Franco-German trade agreement of August 1927 which have a bearing on the ceramic industry. Lists of the products coming under the agreement and of the old and new tariffs are given. The effect on the industry is discussed. A.E.R.W.

Meeting of the German Ceramic Society. ANON. *Ber. deut. keram. Ges.*, **8** [6], 322–76 (1927).—A report of the 8th principal meeting of the German Ceramic Society held at Berlin Oct. 26–29, 1927. F.P.H.

Mining losses. H. E. NOLD. Ohio Ceram. Ind. Assn., *Bull.*, No. 1 (1928).—The survey of clay mining in Ohio now being made by N., shows that the recovery in a large percentage of our underground mines is low, ranging from 17–75% and averaging about 30%. There is no doubt that it can be materially increased, in many cases, without increasing the cost per ton of clay mined. The losses in mining may be classed as avoidable and unavoidable. The unavoidable losses are those made necessary by leaving unmined areas to protect surface works such as buildings, railroads, and streams; the pillars left at the property boundaries; the pillars left around oil or gas wells; some clay left unmined due to poor quality or due to local thinning of the seam and a certain amount of pillar clay which cannot be recovered either economically or safely even when pillar drawing is done in the best possible manner. The avoidable losses are mostly in uncovered pillars and are mainly caused by a lack of foresight in planning and in operating the mine. After the first few years, a large part of the production of the average clay mine should be from the pillars. Other subjects discussed are: (1) principles of pillar drawing, (2) system of mining, (3) why pillars are not drawn, (4) mine projection necessary, (5) an ideal mining system, (6) panel system of mining. F.P.H.

Systematic mining. H. E. NOLD. Ohio Ceram. Ind. Assn., *Bull.*, No. 2 (1928).—See *Jour. Amer. Ceram. Soc.*, **11** [3], 156–68(1928) and *Ceram. Abs.*, **7** [4], 230(1928). F.P.H.

Chemical industry in N. Y. ANON. *Chem. and Ind.*, **47**, 257 (1928).—An introduction, mainly for European visitors, to the industrial side of the Metropolitan district. Among the plants mentioned are those of the General Ceramics Co., Seaboard Refractories, Carborundum Co., Bakelite Co., Johns-Manville, and the U. S. Gypsum Co. H.H.S.

Industrial Transference Board. ANON. *Chem. and Ind.*, **47**, 272 (1928).—A new government department has been established in England to facilitate transference of surplus labor from industries which have a surplus (*e.g.*, the coal industry) to those which have not. H.H.S.

Health conditions in mines. *Chem. and Ind.*, **47**, 374 (1928).—In reply to a question in Parliament, the Minister of Health stated that the health conditions of mines in Cornwall were good, and that no cases of disease due to conditions of employment had been reported. H.H.S.

The Leipzig Fair. ANON. *Morning Post*, March 13, 1928.—The fair this year, with its 46 industrial "palaces" and 15 exhibition halls, is claimed to have been the greatest world-fair ever held. There was a good foreign demand for porcelain ware, especially of the finer sort. This demand for better-class goods, which was reflected in all branches of industry. is regarded as a contrast to pre-war days when "made in Germany" was the hall-mark of cheapness. H.H.S.

Progress of the Common Brick Manufacturers' Association. RALPH P. STODDARD. *Brick Clay Rec.*, **72** [6], 402–408 (1928).—In ten years the Common Brick Manufacturers' Assn. has built up a national organization recognized by the brick industry, the government, and by the professions allied with the construction industry as the representative of the common brick manufacturers of America; has organized and developed 14 district organizations, in constant interchange with the national association; has improved the morale of the industry; has increased the demand for common brick, more styles have been developed, architects have been educated, bricklayer relations have been developed; has increased technical data and has brought out new information on load bearing, fire resistance, insulation, etc., which will make builders and engineers understand the superiority of brick construction; has extended publicity work from practically nothing to national proportions. More than 1000 newspapers receive from one to three pieces of copy per month, and a selected list of 300 newspapers print regularly the association's house plan service. *Building Economy* has been established which reaches 20,000 subscribers. More than $700,000 has been spent for publicity and advertizing. In all of its activities the association has spent about $1,135,000 since its inception; its district groups collectively have spent $2,000,000. E.J.V.

Mechanical devices for heating and power. F. G. JAMES. *Can. Chem. Met.*, **12** [3], 74 (1928).—Mechanical devices which have been brought into use in recent years are described, such as hand stokers, mechanical stokers, pulverizers, oil, and gas. E.J.V.

Society of Glass Technology. ANON. *Pottery Gaz.*, **53** [610], 648vi–48viii (1928).—At the March meeting E. J. C. Bournaker read a paper on "A Method of Testing the Probable Durability of Tank Blocks." W. E. S. Turner outlined some of the preliminary work done in connection with "A Study of a Fundamental Reaction in Glassmaking." E.J.V.

Technical advances in the fine ceramics industry in 1927. W. STEGER. *Keram. Rund.*, **36**, 5–6 (1928).—A review of the literature is given with a bibliography of 103 titles. H.I.

Refining petroleum. ANON. *Chem. Trade Jour. and Chem. Eng.*, **82** [2125], 147 (1928).—An article describing the preparation of bauxite for use in desulphurizing oils, and an explanation of the substitution of clays for sulphuric acid in oil refining. L.P.C.

Rationalization in industry. ANON. *Nature*, **120** [3029], 734 (1927).—Some of the problems of coöperative research in Great Britain are discussed. Management research groups have recently been organized of representatives from firms engaged in different industries. Consequently problems may be discussed freely without the fear of aiding a rival concern. A plea for greater attention to the field of statistical research is also made. C.R.A.

Book Reviews

Ceramic Tests and Calculations. A. I. ANDREWS. Published by John Wiley and Sons, Inc., New York. Price $2.25. This book is as greatly in advance of previously published treatises on ceramic calculations as was the one by A. Heath and A. T. Green an improvement on those of earlier years. It is most timely not alone because all others are out of print but because it presents up-to-date methods and conceptions. This book is recommended for the easily comprehended text and exposition of methods. It should make easier the testing and calculating of mixtures and product properties. The combination of methods of testing and calculating results is new and valuable. For the first time the "slip" calculations are applied to American methods and needs. This has been a feature of the British books on ceramic calculations. These slip calculations could be used more universally. Ample tables of constants and logarithms are appended.

Porcelain. REINH. RIEKE. Second enlarged and revised edition. (Bibliothek der ges. Technik 369.) Leipzig 1928, Max Janecke Publishing House. 7.50 RM. Rationalization, economy of production, and improvement of quality are the viewpoints which today rule the porcelain industry, and necessitate a greater consideration of the process of manufacture and the testing of the products. These requirements are met by the new edition of the Rieke text on porcelain estimation, and the new edition has been enlarged primarily with the object of taking up the methods of testing and the properties of porcelain, as well as with the object of being adjusted to modern requirements with respect to recent scientific work and technical progress. There are many valuable hints for the porcelain manufacturer. The most important service of this work, however, is that it will be a safe guide to anyone who wishes to enter this branch of the industry. Finally, this book will be welcome also to the consumer of porcelain products and to the purveyor to the porcelain industry for the explanation of the nature of the products, and the requirements in raw materials and kilns. It deals with (1) the age of the clay ware industry and the classification of clay wares; (2) the characteristics of porcelain, the classification, composition, structure, constitution, properties and development of the industry; (3) the testing of porcelain and influence of composition upon the behavior of the body and the finished porcelain; (4) raw materials; (5) investigation of raw materials; (6) the manufacture of the body is discussed in the chapters on the estimation and testing of bodies, preparation of the raw materials, and finishing of the body; (7) throwing, casting by means of plaster of Paris forms, manufacture by means of metal forms, and the manufacture of flowers and decorations in the form of porcelain; (8) glazing and firing; (9) decoration of porcelain; and (10) soft porcelain. An appendix contains approximate atomic weights, chemical formulas, and molecular weights. An excellent subject index makes possible rapid reference.

Sprechsaal Kalender 1928. Edited by Dr. J. Koerner. Published by Müller and Schmidt, Coburg. This handy diary has 216 pages devoted to abstracts of the scientific data which are of value to ceramists. To those who make ceramic investigations involving silicate reactions, the Sprechsaal Kalender is very valuable as a quick and reliable reference to most recent investigations and the most recently established constants, values, and reactions.

Tonindustrie Kalender 1928. Published by Verlag: Chemisches Laboratorium für Tonindustrie und Tonindustrie Zeitung, Berlin. The annual bibliography and review issued in pocket-size books constitutes one of the most accurate records of ceramic progress. The Kalender for 1928 gives considerable space to that neglected but important subject of ceramic masonry and the quality requirements of ceramic products. These Kalenders, when reviewed over a period of years, show the industrial benefits

which have developed from painstaking determination of physical and chemical constants and laws and especially when applied to the specific ceramic industrial problems.

The Story of Armco. Published by the American Rolling Mill Co., Middleton, Ohio, 1928. A wealth of information is given concerning the institution and its many products. Chapter titles include "The Origin and Development of a Great Iron and Steel Company," "Research Pioneers in Iron and Steel," "Advertizing Armco Products and Service to the World." Another tells how Armco is "creating and supplying a world market for specialty products." The concluding section is devoted to a discussion of policies that have proved dependable and enduring. Particularly interesting to manufacturers of porcelain enameled products as well as students of this great modern industry, is the section on page 14 entitled "Give us an Enameling Iron that Will Hold Enamel Tightly." Under this subject the difficulties encountered and obstacles surmounted in producing this iron are recounted. Copies may be obtained from the publicity department of the American Rolling Mill Co., at Middleton, Ohio.

Department of Scientific and Industrial Research. Building Research. Special Report No. 8. (H.M. Stationery Office, London, 1927.) vi+58 pp., 27 text figures, and 1 plate. Price 1*s* 6*d* net. The resistance of building materials to fire is dealt with. Part I contains a brief outline of the effect of high temperatures upon materials in general, metals, timber, natural stones, bricks, etc.; while Part II is devoted to the fire-resistance of concrete. The deterioration produced in concrete by fire is shown to be due to two main causes, one being the thermal expansion of the aggregate and th other the presence of free lime, which is dehydrated at the temperature attained in a building conflagration and slakes with expansion on subsequent exposure to moisture, causing complete failure of the structure. The tests reported show that a good deal of the free lime in Portland cement concrete may be absorbed by the addition of pozzuolanas, the resultant concrete showing, in some cases, a considerable degree of stability, when exposed to the high temperatures; the value of various pozzuolanas for the purpose is discussed. Research on the lines of the work described in the Report is still proceeding. The special mixtures of Portland cement and pozzuolanas have been kept under observation for over two years, both in the normal condition and after exposure to fire, and seem perfectly reliable. A further report will be published after five years' experience has been obtained. (*T.E.C.S.*)

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A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific, and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIAL

COÖPERATION BETWEEN ARTISTS AND MANUFACTURERS[1]

BY E. DE F. CURTIS

Two years ago, at Atlanta, the Art Division became actively interested in the problem of getting more trained artists into the ceramic industries. We have made some progress and we feel gratified with some of the results obtained and with the plans now under way, but the actual solving of such a problem will require several more years of real effort. As a further investigation along this line I tried to find some guide or parallel in the methods employed in other industries in their efforts to obtain suitably trained designers.

In 1922 the National Society for Vocational Education and the Department of Education of the City of New York subscribed $60,000 for this kind of survey, under the direction of Charles R. Richards. The results were published under the title, "Art in Industry." The investigation was made in many lines of endeavor; the clothing trades, textiles, ceramics, woodworking, printing, silver, wall paper, jewelry, ornamental hardware, etc. The applications may be quite different in ceramics but the underlying features are most significant.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlantic City, N. J., February, 1928.

Besides studying Mr. Richards' book I have discussed the question with architects, school principles, building construction superintendents, museum directors, retail dealers, and industrial art directors and the following conclusions are offered for consideration:

(1) It was found that in nearly every industry the stimulus came from some economic crisis. The issue was forced by some substitute material becoming more popular, by foreign competition, or by the necessity of creating designs that had been obtained elsewhere, such as the condition that obtained in many lines during the war; in other words, a realization that the public wanted something better.

(2) These industries have found it necessary to influence public taste and approval by every intelligent means: through their trade organizations; by means of lectures, given by broadly educated people before women's clubs, department stores, at trade expositions; by means of newspaper advertisements, displays, annual exhibitions, prize competitions; and particularly through the education of the retail salesmen.

(3) The need is not for more designers but for better designers, more broadly educated, more cultured, and better able to adapt themselves to factory practice.

(4) The designers who work up through the industry lack this broad outlook and those who come from the schools lack technique.

(5) The schools, in general, have no practical men in charge who still maintain their trade relations.

(6) It is necessary for the industry to assume some responsibility for the graduate and the industry must not ask the school to cater to temporary trade needs.

(7) A good designer is a valuable man, commanding up to $25,000 a year.

(8) There is a definite need for a design registration law to prevent pirating of designs.

These conclusions may be condensed into three steps: (1) the need by the factory, (2) the production of the designer, (3) the acceptance of the responsibility by the factory.

To apply these steps to our own ceramic industries it is suggested that each factory making a product containing any element of design should consider the source of the design, weigh it carefully, and endeavor to improve it.

There is no question that other industries are stressing the quality of design in their products. It is only necessary to read the advertisements of wall papers, textiles, ornamental hardware, etc., to realize that they understand the value of design; for example: Packard, the car that originated standard automobile design; Essex, beauty to

match their super-six performance; Ford, beauty of line and color; Graham-Paige, Lorado Taft designed this symbol; Corona in colors; color the vogue in fountain pens; General Motors offers an increasing measure of beauty in design; Frigidaire calls attention to the modern trend toward decoration in the kitchen. The great amount of paid space used in stressing the decorative features is amazing.

This is the beginning of a new period in industrial art. The industries are realizing that the creations of the individual can be produced without losing the spirit of the work. The museums have big caliber men as associates in industry. The American Federation of Arts has incorporated a division of Industrial Art in the organization. The decorative arts are coming into their proper place. What is the ceramic industry doing to keep in step with this new trend?

The Art Division does not know what is being done. We can trace design through the table ware plants to the decalcomania firms; through the tile plants to interior decorators, architects, and tile dealers; through the terra cotta plant to the architect; beyond that we cannot go without help from the industry; we can only judge by occasional contacts. A young graduate architect, whose work was so expert that he barely missed the Prix de Rome, stated that no tile would stand our climate. A building superintendent for a big construction company says that his company always tries to swing the architect away from terra cotta and at the same time remarks that one of the big problems is the embellishment of the concrete structure.

Until these impressions are overcome ceramic art cannot reach the heights for which it is justified in striving.

The Art Division stands ready to help in any way possible and to supplement the contacts that are now chiefly those of buyer and seller.

We strongly urge that the various industrial Divisions of the Society appoint a representative to advise with the Art Division as to definite methods of approach to bring about the coöperation so necessary to the advancement of ceramic art.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM APRIL 1 TO MAY 1

CORPORATION

Shenango Pottery Co., Manufacturers of hotel vitrified chinaware, New Castle, Pa. James M. Smith, representative.

PERSONAL

M. A. Besborodov, Manager of Laboratorium of the Glasstrust Drushnaya Gorka, U. S. S. R., Leningrad District.

William John Bucklee, 11 Broadway, Sales Engineer, Celite Products Co., New York City.

Herbert Duane Carter, 3293 E. 143rd St., Chemist, Ferro Enameling Co., Cleveland, Ohio.

Hugo Adolf Dahlquist, Superintendent, German Norton Co., Wesseling bei Köln, Germany.

Paul Russell Dreyer, Industrial Engineer, Peoples Gas, Light, & Coke Co., 122 S. Michigan Ave., Chicago, Ill.

Alexis Froeberg, Manager of Refractory Dept., Glasstrust Drushnaya Gorka, U. S. S. R., Leningrad District.

Robert S. Graetz, 306 Davis St., Technologist, Adamston Flat Glass Co., Clarksburg, W. Va.

Max L. Gunnarson, Superintendent, Globe Tile and Porcelain Works, Inc., Hynes, Calif.

Tao Hou, Instructor, Ceramic School of Kiangsi Province, Pao-Yang, Kiangsi, China.

Joseph Fraser Hyslop, J. G. Stein and Co., Ltd., Bonnybridge, Scotland.

Louise Kitchen, The Red Barn Studio, 2205 Parkwood, Toledo, Ohio.

Frederick C. Sammons, Sales Manager, Vitrefrax Corp., Los Angeles, Calif.

STUDENT

William Horak, University of Illinois, Urbana, Illinois.

Drury Dickson Turner, Ohio State University, Columbus, Ohio.

Membership Workers' Record

CORPORATION	
Office	1
PERSONAL	
J. G. Callinan	1
M. L. Fosdick	1
C. H. Griffen	1
V. K. Haldeman	1
Karl Hart	1
F. E. Hodek, Jr.	1
R. D. Landrum	1
L. E. Putnam	1
Alan Stein	1
W. W. Tsou	1
Office	2
Total	12

STUDENT	
J. J. Svec	1
A. S. Watts	1
Total	2
Grand Total	15

Result of Vote on Amendments to the Constitution

The report of the Committee on Rules states that sufficient votes have been cast for adopting all amendments to the Constitution as recommended by the Committee and published in the *Bulletin*, 7 [3], 59–61 (1928).

NEWS FROM THE LOCAL SECTIONS

Michigan-Northwestern Ohio Section[1]

The Section met on May 8 at the Detroit Engineering Club House. H. G. Wolfram, Director of Research for the Porcelain Enamel and Mfg. Co., Baltimore, Md., presented a paper on "Practical Enameling and Technical Control."

This Section held a joint meeting with the Detroit Engineering Society on April 13. C. E. Bales, production manager of the Ironton Fire Brick Co., Ironton, Ohio, talked on "The Modern Trend in Technology of Refractories," presenting many of the new methods in regard to the testing of refractories in the way of spalling, slag tests, etc.

At the March 15 meeting of this Section a moving picture entitled "The Age of Speed," was shown by courtesy of the Norton Co. R. C. Purdy gave a talk on the Ceramists' Tour Abroad.

A. H. Fessler of Flint, Mich., was elected vice chairman of the Section.

St. Louis Section

Thirty members of the St. Louis Section of the AMERICAN CERAMIC SOCIETY motored to Rolla, Mo., April 28 for a joint meeting with the staff and students of the ceramic department. The program was as follows:

10:30 A.M.–12:30 P.M. Inspection of laboratories

12:30–1:30 P.M. Get-together luncheon, Parish House

1:30–2:45 P.M. Technical session

Front row (left to right): (1) H. W. Perry, (2) R. Miller, (3) David Larkin, (4) Frederick E. Bausch, (5) Major E. Holmes, (6) and (7) Senior students, ceramic engineering, Rolla School of Mines.

Top row: (4) H. A. Buehler, (6) H. E. Wiedeman, (7) J. L. Crawford, (9) H. S. McQueen, (10) V. J. Azbe, (12) Bud Hunkins, (14) Carl Green.

Second row: (last man on right) A. Vollmer, Jr.

The speakers at this session were C. H. Fulton, director Missouri School of Mines; Foster Holmes, general manager of Evens and Howard Fire Brick Co.; J. L. Crawford, ceramic engineer for Laclede-Christy Clay Products Co.; H. A. Buehler, Missouri

[1] E. B. Baker, Secretary-Treasurer.

State Geologist; W. K. Schweickhardt, senior ceramic engineering student; and M. E. Holmes, professor of ceramic engineering.

2:45 P.M. Trip to Forbes diaspore pit, with a lecture by H. S. McQueen. Golf optional

3:45 P.M. Trip to Meramec Springs

LADIES PROGRAM

10:30 A.M.–12 M. Inspection of laboratories and grounds

12:00–3:30 P.M. Luncheon bridge at the residence of M. E. Holmes, 1111 State St.

3:45 P.M. Trip to Meramec Springs

During the past year the new ceramic department of the Missouri School of Mines has been rounded out and the laboratories fully equipped, the equipment being supplied by the fire products manufacturers of the state of Missouri.

Two students are to be graduated this year, one in ceramic technology and one in ceramic engineering. The enrollment has increased from three last year to thirty-one this year, with indications that the enrollment next year will reach forty. All the students, with the exception of a few freshmen, will be leaving soon for their summer work in ceramic plants.

The Missouri Clay Testing and Research Laboratories, operated under the direction of the ceramic engineering department, have made steady progress during the past year, the average amount of work now being about seven times that of a year ago.

Among those present at this meeting were: H. W. Perry, superintendent of the Laclede-Christy Clay Products Co.; R. Miller, works manager of the Farber Fire Brick Co.; David Larkin, president of Larkin Engineering Co.; Frederick E. Bausch, Frederick E. Bausch Co.; M. E. Holmes, head of Ceramic Engineering, Rolla School of Mines; H. A. Buehler; Alex Langsdorf, head of research department, Washington University, St. Louis; H. E. Wiedeman, chemist, St. Louis; J. L. Crawford of Laclede-Christy Clay Products Co.; H. S. McQueen; Victor J. Azbe, consulting engineer of St. Louis; Bud Hunkins of Hunkins-Willis Lime & Cement Co., St. Louis; Carl Green of Laclede-Christy Clay Products Co.; and A. Vollmer, Jr., president of the St. Louis Pottery Co.

NOTES AND NEWS

Sixth National Colloid Symposium

The Sixth National Colloid Symposium will be held at the University of Toronto June 14–16. H. B. Weiser of Houston will be chairman, E. F. Burton of the department of physics, secretary. W. B. Hardy of Cambridge, England, is to be the guest of honor. Arrangements have been made for an exhibition of experimental methods in colloidal work.

Ohio Ceramic Industries Association Meetings

Members of the Whiteware Section of the Ohio Ceramic Industries Association held a meeting on May 24 at East Liverpool, Ohio, in the U. S. Potters Association headquarters.

The chairman for the afternoon and evening sessions was Malcolm Thompson of the Hall China Company. Papers were presented by A. S. Watts on "Survey of the Whiteware Industry;" Frederick H. Rhead on "Fundamental Problems in Ceramic Art Development;" W. Keith McAfee on "The Educational and Research Program of the Association."

A business session completed the afternoon session.

At the evening session A. S. Wells talked on "Mechanical Development;" J. E. Boudreau on "Art and Mechanical Production;" and A. V. Bleininger on "Some Physical Facts in Relation to Ceramic Production."

On May 11 members of the Heavy Clay Section of the Association inspected the experimental unit at the Roseville Brick Plant.

Luncheon was served at the prison followed by a business session in which a report on the heavy clay and refractories survey of the state was given. Plans for coöperative research were discussed and a plant demonstration of the equipment at the Roseville plant was presented.

CALENDAR OF CONVENTIONS

American Ceramic Society		
Annual Meeting	Feb. 1929	Chicago, Ill.
Ceramists' Tour Abroad	May 19–July 5	
American Electrochemical Society		
(Fall Meeting)	Sept. 20–22	Charleston, W. Va.
Amer. Soc. Mech. Engr.		
(Regional)	Aug. 27–29	St. Paul-Minneapolis
(Regional)	Oct. 1–3	Boston, Mass.
Amer. Soc. Steel Treating		
(Annual Meeting)	Oct. 8–13	Philadelphia, Pa.
Canadian Natl. Clay-Products Assn.	June 13–15	Montreal, Quebec
Mfg. Chemists Assn. of U. S.	June 2	New York City
Natl. Assn. of Mfgrs.	October	
Optical Soc. of Amer.	October	Washington, D. C.
Safety Congress	Oct. 1–5	New York City

The following numbers of the *Journal* and *Transactions of the American Ceramic Society* are out of print:

Journal of the American Ceramic Society

June, 1923
January, 1924
February, 1924
January, 1925
January, 1926
March, 1927
January, 1928

Transactions of the American Ceramic Society

Volume II, 1900
Volume IV, 1902
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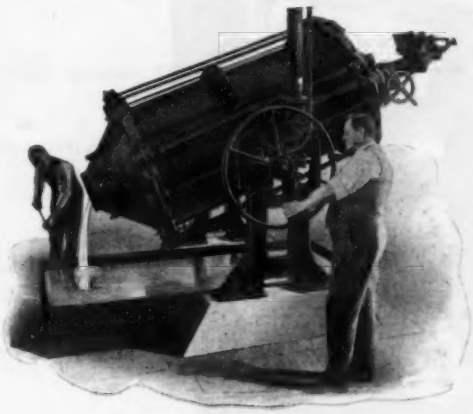

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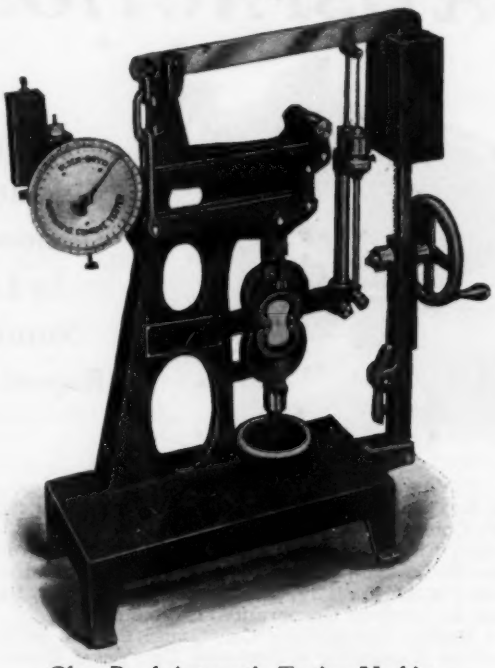

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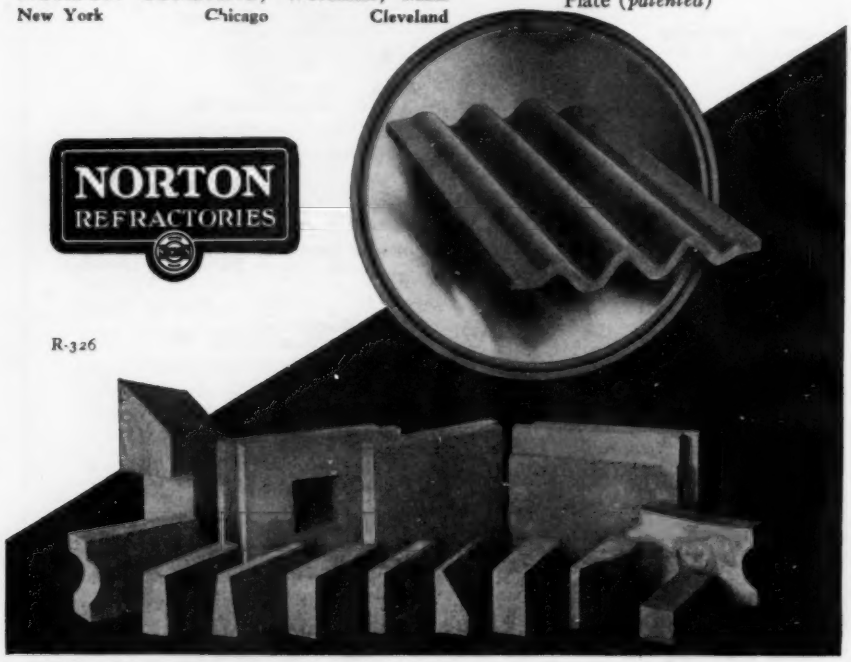

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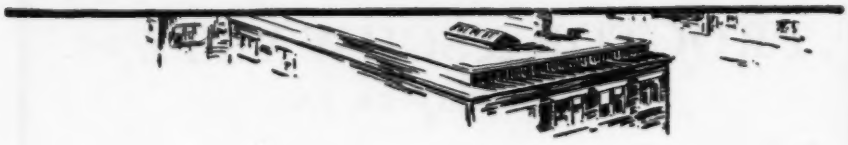

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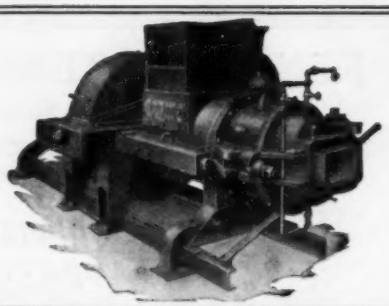

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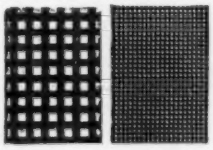

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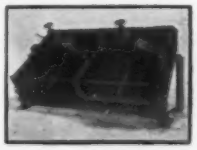

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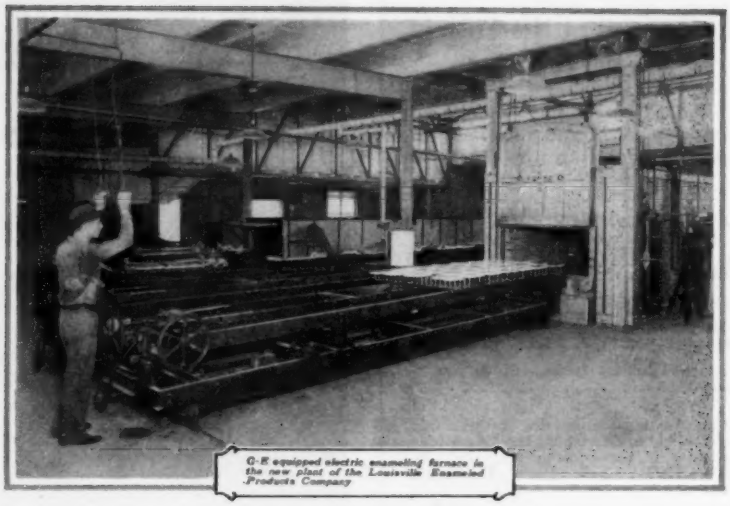

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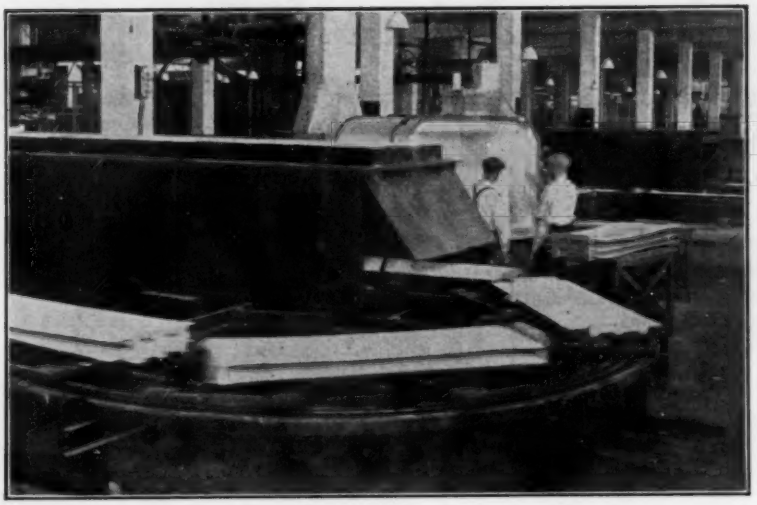

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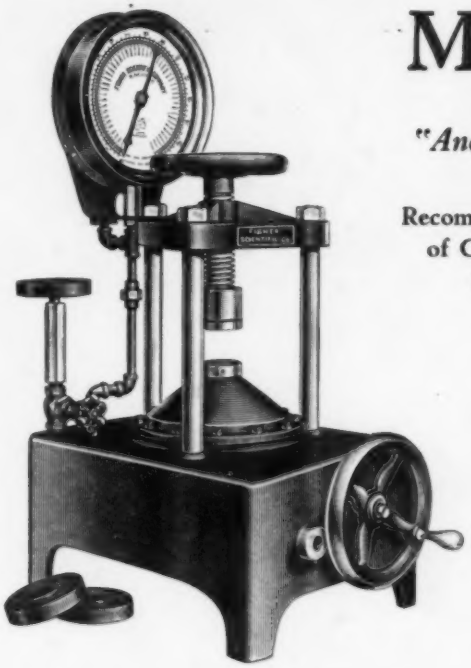

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